ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD COMPANY
SUBURBAN SERVICE AT CHICAGO, ILL.

BY TRACY W. SIMPSON

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TRACY W. SIMPSON

A THESIS

SUBMITTED TO THE COUNCIL, AND FACULTY OF
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OF
ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF
BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

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LETTER OF TRANSMITTAL

Chicago, Ill.

To the Council and Faculty of the
Department of Electrical Engineering.

Armour Institute of Technology,

Chicago, Ill.

Gentlemen:-

I have the honor to submit herewith a thesis for the degree of

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

This thesis is a study of the suburban system of the Illinois Central Railroad Co. at Chicago, Ill. with particular reference to its operation by electric motive power. In addition it is an exposition of certain methods of procedure for attacking a problem of this kind, and also it includes various studies of engineering interest that are related to the general question of the electrification of steam railroads. In these last respects the work necessarily differs from an engineer's report to the railroad company as client; but as far as possible, these technical descriptions of method etc. have been included as appendices.

Respectfully submitted,

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[illegible]

The suburban service at the Chicago terminal of the Illinois Central Railroad is at the present time, the best example of [illegible] service operated by steam locomotives to be found in the United States. It has long been regarded by the railroad company as an important and integral part of the company's business; and the excellent manner in which the equipment is operated and maintained, and the general business of the suburban service is conducted show unmistakably the careful supervision under which it is operating. These conditions are in distinct contrast to the policy of some [illegible] railroads [illegible] allow the suburban service to take care of itself, donating to it annually whatever worn out locomotives [illegible] it may have [illegible] available.

Certain conditions following the World's Fair of 1893 gave the Illinois Central Railroad Company the opportunity to institute a suburban service in advance of [illegible] system, and [illegible] the opportunity was grasped and developed is a matter of railroad history. The [illegible] policy [illegible] has been [illegible] many lines since. Perhaps the most apparent example of this has been the [illegible] of the multiple unit [illegible] in 1897, a time in which all [illegible] the [illegible] service.

In view of the [illegible] attention upon the recent change to electric operation on some portions of the New York Central, New Haven, Pennsylvania, and Erie railroads, it is particularly important to [illegible] the applicability and [illegible] results

to be expected now is a change from steam to electric operation for the suburban service of the Illinois Central Railroad Company. In 1894, the company employed a commission to investigate the possibilities of electric traction for this service, but owing to the incomplete state of development of electric railway machinery, the commission was justified in reporting adversely. Since that time electric railway equipment has attained a high order of excellence; and although some questions of engineering policy still give rise to argument, the way is very clear to a definite and final decision as to the best system to use and the excellent results to be realized by its adoption.

TERRITORY SERVED

The map, Fig. 1 illustrates territory served by the I. C. R. R. suburban service. From Randolph St. to Grand Crossing the railroad traverses a thickly settled residence district providing a heavy commuter traffic. From Grand Crossing to Burnside, the territory is sparsely populated and will not admit of much development on account of its low elevation. At Burnside are situated the extensive shops of the railroad. Pullman and Kensington are manufacturing districts of note. Kensington is the terminus of the Michigan Central Railroad which uses the Illinois Central tracks from this point into Chicago. It is also the terminus of the Chicago Lake Shore and South Bend Ry., a high class interurban electric railroad operating a single track line to South Bend, Indiana via Hammond, Gary, and Michigan City. That portion of the road from Hammond to Kensington is owned by a subsidiary Illinois Central corporation, — the Kensington and Eastern.

[illegible] [illegible]. The [illegible] [illegible] [illegible] has [illegible] [illegible] [illegible] single car trains on a one hour headway at maximum speeds approaching 50 M. P. H.

South of Kensington the town of Harvey has 6800 inhabitants and is a growing residential and manufacturing town. From Harvey to the terminus of the suburban service at Flossmoor, the country is rolling and above the Chicago Plain. The chief town is Homewood of 800 inhabitants. At Flossmoor is situated the Homewood Country Club. For most of the region south of Grand Crossing to Harvey, a great development is expected when the Calumet Drainage projects are completed; but at present the tendency is to retrogression in most of the Calumet region. South of Harvey the country is undergoing healthy development as a high class suburban residence district.

The South Chicago branch reaches a combined residential and industrial territory. Here are situated the Illinois Steel Co. South Works, and the Deering Works of the International Harvester Company. The Blue Island branch reaches excellent suburban country west of Kensington. West Pullman is the chief town. Here are the Plano Works of the International Harvester Company, etc. Blue Island has 8000 inhabitants, but is well served by the Rock Island suburban system.

Following is a table of distances in miles from Randolph St. and distances between stations for all points on the I. C. R. R. suburban system.

TABLE I

TABLE OF STATION DISTANCES I. C. R. R.

Randolph St.	.19				
Van Buren St.	.83	.64	Van Buren St.	.83	
Central Sta. (Park Row)	1.45	.62	Combination Switch	1.40	.57
16th St.	2.00	.55	Hyde Park	6.57	5.17
22nd St.	2.52	.52			
26th St.	3.03	.49			
31st St.	3.59	.56			
Douglas	4.18	.59			
Oakland	4.61	[illegible]			
43rd St.	5.25	.64			
47th St.	5.82	.57			
Madison Park	6.23	.41			
Hyde Park	6.57	.30			
South Park	7.07	.50			
60th St.	7.49	.42			
Woodlawn	7.90	.41			
67th St.	8.40	.50	67th St.	8.40	
Brookdale	8.76	.36	Parkside	9.11	.71
Essex	8.98	.22	Bryn Mawr	9.61	.50
Grand Crossing	9.48	.50	South Shore	10.12	.51
Drexel	10.29	.81	Windsor Park	10.73	.61
Woodruff	10.83	.54	Cheltenham	11.39	.66
Dauphin Park	11.30	.47	[illegible] St.	11.84	[illegible]
Burnside	11.98	.68	[illegible] St.	12.43	[illegible]
104th St.	13.11	1.13	South Chicago	12.81	[illegible]
Pullman	13.98	.87			
[illegible]	14.84	.86	[illegible]	14.84	
Wildwood	16.05	1.48	State St.	[illegible]	[illegible]
Riverdale	17.22	1.19	Stewart Ridge	16.03	[illegible]
147th St.	19.03	1.81	West Pullman	16.59	[illegible]
Harvey	20.07	1.04	Plano	17.03	[illegible]
Hazel Crest	22.17	2.10	Ashland Ave.	17.66	[illegible]
Homewood	23.54	1.37	Burr Oak	18.30	[illegible]
Flossmoor	24.92	1.38	Blue Island	18.88	[illegible]

TRAIN SERVICE

Train service from Randolph St. is divided as express or local. Express trains run from Van Buren St. to Hyde Park without stop and on the east pair of tracks of the right of way. These have been isolated from the other tracks, not being cut into by switches or crossovers so that delays rarely occur. From Hyde Park to 67th St. these separate tracks are used for the express service. At 67th St. the express trains

continue to South Chicago, Flossmoor, or Blue Island as the train may be designated. Local trains run from Van Buren St. to Woodlawn on the west pair of tracks. Local trains stop at all stations shown on Fig. 1 between those points. Local trains are made up of multiple side door cars, whereas all other trains use the older type car with end doors.

Various classes of train service are provided, some details of which are shown in Table II. This data is compiled from a summer week day schedule. In winter some Flossmoor trains run only as far as Harvey. In addition to the trains noted in Table II, there are a few trains during the rush hour which cannot be included in the classification of Table II. Usually one express each to Burnside, West Pullman, and Kensington is provided. These trains have been considered as regular trains to Flossmoor and Blue Island in compiling the table. A service of four trains a day each way is provided on the Rockford division, between Randolph St. and Addison, 24.1 miles. These leave city via St. Charles Air Line. Further details of the present steam schedule are included in the printed time table of the service a copy of which is included herewith as Table III and from which Table II has been compiled.

TABLE II

DETAILS OF TYPICAL PRESENT SUBURBAN SERVICE

SUMMER WEEK DAY.

	LOCAL	EXPRESS			
Randolph St. to	Woodlawn	South Chicago	Blue Island	Flossmoor	Grand Crossing
Distance Miles	7.9	12.9	18.0	24.9	7.8
Time minutes	28	35	47½	57½	24
Number of Stops	15	14	[illegible]	21	9
Length average run miles	.53	.92	.82	1.13	1.10
Schedule speed M.P.H.	16.9	22.1	17.9	26.2	20.0

	[illegible]		[illegible]		
	Randolph St. to Woodlawn	South Chicago	Blue Island	[illegible]	Grand Crossing
Number trains each way per day	67c	[illegible]	15	10	7
Headway minutes [illegible]	[illegible]	–	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] 20 min., [illegible] min.

[illegible] 119

Notes:-

c [illegible] Woodlawn and [illegible].

a Making all stops. [illegible] Ashland Ave. [illegible] only Ashland Ave. [illegible]

b Making all stops except Drexel and [illegible]. Schedule time including these 64 minutes.

d [illegible]

[illegible] table [illegible] service [illegible] Table [illegible]

[illegible]

[illegible]

[illegible] [illegible]

NUMBER OF CARS PER TRAIN

At the present time midday locals are two car side door trains, and midday express trains average four cars. Rush hour locals are either three side door cars or six end door cars. Rush hour expresses are usually made up with seven end door cars.

TRACK AND ROADWAY.

Figures 2, 3, and 4 show profile and alignment for the suburban tracks as well as other features of permanent way; - types of ballast, and weight and age of rails. Fig. 5 shows in greater detail the yards of the company at Chicago terminal as far as they are related to the suburban service. From Kensington south to Flossmoor, the suburban trains operate on main line tracks; but from Kensington to Randolph St., they occupy tracks devoted exclusively to suburban service. From Van Buren St. to 67th St., east tracks are used for express trains and loading platforms separate from the local platform are provided. Express tracks are cut into by crossovers only at 27th St. and 43d St. in the entire 7 miles between 12th St. and 67th St. At 12th St. all incoming express trains stop for signal at the combination switch before proceeding across the yard tracks to track 2. The yards of the company are arbitrarily divided at this point so that it is only on rare occasions that a train is delayed due to freight switching. Under agreement with the City of Chicago, that portion of the right of way extending from 12th St. to Randolph St. must contain no structures reaching above the retaining wall marking the edge of Lake Front Park. When the new outer parkway is completed, the right embodied in this agreement is liable to be most carefully guarded. This fact has an important bearing on the question of proper structures for a power distributing system with electric operation.

There are no grade crossings north of Drexel. From 51st St. to Drexel the tracks are elevated and streets are crossed on viaducts of the usual plate girder type. It is as yet undecided whether there shall be separation of the grades of the Illinois Central R. R. and the Pennsylvania R. R. at Grand Crossing. All grades are very light, and there are no curves for which a slow down in speed is required by suburban trains.

The total track mileage operated in the suburban service is 80.0 miles including sidings at Randolph Street.

STATIONS.

The type of station employed usually consists of a frame or brick depot built adjacent to the right of way with a loading platform, usually of the island type, to which admission is had by means of turnstile at the ticket seller's window. The platforms are raised to the level of the car floor (4 ft. above rail), and are provided with shelters and canopy roofs. South of Kensington, where main line tracks are used, the platforms are at rail level and hence egress from car is by means of steps. At Randolph St., six tracks are served by three island platforms admission to which is by means of steps leading from an overhead covered bridge spanning all the tracks. At Van Buren St. a suburban station has been provided, comprising a station building 300 ft. long and 60 ft. wide, as well as platforms aggregating about 1000 ft. in length along each side of tracks 1 and 2. Two trains can be loaded at once at Van Buren St. The main depot of the railroad is

[illegible] at 12th St. [illegible] trains do not enter this station. There is located, however, near it, a complete local suburban station but it is operated independently. The average length of station platforms is 500 ft. This will permit of loading a train of eight standard suburban cars or of [illegible] side door cars.

The stations, [illegible], and platforms, including also the general offices at Central Station, are lighted by incandescent and arc lamps supplied with current from the company's service plant at 25th St. [illegible] suburban stations as far south as [illegible] are supplied from this system [illegible]. Transmission is from [illegible] and 2,300 [illegible] of [illegible] volts 60 cycle 3 phase to transformers at local points.

ROLLING STOCK.

There are in use 40 locomotives of the [illegible] type built especially for suburban service. The various classes now in use and [illegible] are shown below in Table II.

TABLE II.

[illegible] [illegible] I. C. R. R. SUBURBAN LOCOMOTIVES.

Type	[illegible]	[illegible]	[illegible]	[illegible] (a)
Number in use	21	10	2	7
Cylinder dimensions	16x22	[illegible]	[illegible]	[illegible]

Driving wheel diameter	56 1/2	[illegible] 1/2	[illegible] 1/2	[illegible] 1/2
Wheel Base	[illegible] ft. [illegible] in.	[illegible] ft. [illegible] in.	[illegible] ft. [illegible] in.	[illegible] ft. [illegible] in.
Total weight tons	59	8[illegible]	[illegible]	[illegible]
Weight on Drivers	28	36	[illegible]	[illegible]
Tractive Power, 20% adhesion	11200 lb.	15400 lb.	[illegible] lb.	[illegible] lb.

(a) Re-built ten wheelers.

[illegible] locomotives are [illegible] [illegible] [illegible] and [illegible]. [illegible] large boiler [illegible] [illegible] [illegible] [illegible] to maintain high [illegible] [illegible] [illegible] to a considerable speed.

Certain observations on the acceleration of trains [illegible] [illegible] [illegible] [illegible] are shown in Table 6.

Table 6.

[illegible] accelerations of [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible]

Type of Loco.	No. of Cars	Wt. of Train Tons (total)	Distance Feet Observed	Time Sec.	[illegible] Ft./Sec./Sec.	[illegible]
[illegible]	[illegible]	16[illegible]	[illegible]	10	.[illegible]	Light load
"	[illegible]	1[illegible]	240	[illegible]	.7[illegible]	" "
"	[illegible]	[illegible]	[illegible]	[illegible]	.[illegible]	" "
"	[illegible]	[illegible]01	[illegible]	[illegible]	.6[illegible]	" "
[illegible]	[illegible]	1[illegible]	[illegible]00	[illegible]	1.00	" "
—	[illegible]	[illegible]	[illegible]00	[illegible]	.[illegible]	Heavy load
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.[illegible]	"
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.[illegible]	"

These are obtained from stop watch tests of the time required for a train to travel various distances up to its own length. In all cases best performances are tabulated. The performances agree fairly well with calculated results on the basis of 20% adhesion. The observed accelerations are not continued for any length of time. Almost immediately after a train has traveled about 300 ft., the process of notching up was begun which reduced the rate of acceleration. The speed at which the notching up of the first locomotive is begun is about 17 m.p.h. This is about the point of maximum horse power of the locomotive. On this basis the unit horse power of the various locomotives appears as from [illegible] H.P. for the 2 - 4 - 4 type to 900 H.P. for the 2 - 6 - 4 type.

From data of Table V and from other time - distance tests, Fig. 6 is derived. This is a speed time curve from a run of 0.815 miles as performed by present steam equipment. It is the estimated best performance of a 2 - 6 - 4 locomotive hauling three side door cars loaded, and also represents fairly well the best performance of a 2 - 4 - 4 locomotive hauling two side door cars.

The cars used for the suburban service are of two types, the multiple side door car and the standard end door car. The side door car is at present used on the Woodlawn local trips. 17 of these cars are now in use. Table VI shows comparative data regarding these types of cars.

TABLE VI.

COMPARATIVE DIMENSIONS. I.C.R.R. SUBURBAN CAR EQUIPMENT.

	Multiple Side Door	Standard End Door.
Length over all ft.	71	51

Length over end sills ft.	64	45
Width over sheathing	10 ft. 5 in.	[illegible] ft. [illegible] in.
Weight of Body (equipped)	61400 lb.	[illegible] lb.
Weight of Trucks	21400 lb.	16800 lb.
Total weight	82000 lb.	[illegible] lb.
Seating capacity	100	[illegible]

The side door cars are strongly built. A complete steel underframing is provided composed of four longitudinal 9 in. 21 lb. I beams tied together with 6 - 7 in. 15 lb. I beams between two end sills of 9 in. 25 lb. channel. Diagonal bracing and gusset plates are used at corners and at body bolster support. The floor is 1/4 in. deck plates riveted directly to underframing. The super structure is semi steel construction. The side doors are operated by compressed air and an electric signal circuit is arranged so that when all doors on train are closed, the fact is instantly communicated to the engineer. These cars have been in use for five years and have given good satisfaction in handling crowds. The signal device works perfectly, controverting the statements of certain railway engineers that such a device is impracticable. The cars are necessarily heavy on account of the necessity of furnishing all supporting strength in the underframing; it being impossible to frame around the side doors.

The short stops made possible by the use of these side door cars is a matter of importance in suburban service. The writer has frequently timed a three or four car train of side door cars loading at Van Buren St. during the rush hours where 150 to 200 people board the train. Duration

of stops averaged 14 [illegible] seconds have been timed and at no time has the [illegible] 15 seconds to be exceeded. In other stations the results are equally as satisfactory, [illegible] to twelve seconds sufficed for a complete station stop during rush hours. With a train of [illegible] and door cars, the duration of station stop at Van Buren St. is from 20 to 40 seconds, depending on platform congestion. At other stations, the stops are from 12 to 20 seconds during rush hours. The side door cars seems to save from 8 to 20 seconds per stop as compared with the end door cars. The greatest congestion usually occurs at the time of heaviest loading; just when such a saving is the most desirable.

Another distinct advantage of this type of car is the impossibility of any person getting on or off or [illegible] themselves to the track. This eliminates personal injuries as a factor of operation. The greater safety in the matter of accidents at the heavy concentration [illegible] is an important consideration, [illegible] is not so [illegible] in the case of [illegible] trains consisting of [illegible] cars. A [illegible] at Van Buren St., [illegible] the speed is approximately [illegible], would be extremely [illegible] with present [illegible], [illegible] at least.

[illegible] AND CAR STORAGE.

Besides the [illegible] tracks at Randolph St., there is provided [illegible] storage tracks available for [illegible] cars aggregating 3000 ft. in length. This will provide room for 50 side door cars. The tracks

are ten in number, extending from Randolph St. to Harrison St., and are directly east of tracks 1 and 2 as shown in Fig. 6. At the outer suburban terminal ample storage sidings are available which can be easily extended. Light car cleaning and inspection is done on the downtown storage tracks. The locomotive storage yard, coaling and inspection sheds are at 26th St., with an auxiliary coaling station at Randolph St. It is customary to dispatch locomotives released at Randolph St. to 26th St. immediately.

The main car repair and locomotive shops are at Burnside at the general company shops.

SIGNAL SYSTEM.

The present suburban tracks are protected by electric block signals of the Hall Banjo type. The suburban tracks are controlled at the same points as the main line tracks by means of signals mounted on overhead bridges spanning the entire set of tracks. In addition to these, other signals are provided where necessary, mounted on standards adjacent to the track controlled. These signal positions are indicated in Figs. 2, 3, and 4. Simple block signaling only is provided, no overlap signals being used.

EARNINGS OF PRESENT SUBURBAN SERVICE.

The preceding paragraphs have briefly described the physical equipment of the present suburban service. The writer has been unable to obtain figures of earnings and operating costs,

The omission of [illegible] [illegible] [illegible], [illegible] a general statement that about [illegible] passengers are handled [illegible] [illegible] will suffice to show the extent of the present traffic. There are however, certain facts regarding the service that are plainly apparent. The suburban traffic is decreasing on account of the competition of the rehabitated lines of the Chicago City Railway and of the South Side Elevated R. R. Fig. 7 shows the relations of these lines to the I. C. R. R. [illegible] in 1903 and in [illegible].

The Chicago City Railway has in use 45 ft. double truck cars each having 4-40 H.P. motors, which have been substituted for the cable equipment and single truck electric cars. The speeds have been increased and routes provided that permit travel to the city from Illinois Central territory without transfer. The lines on which these cars operate are in direct competition with the Illinois Central R. R. at Grand Crossing, 57th St., 47th St., and 43rd St. In addition, it parallels the I. C. R. R. from 39th St. to Randolph St. From each of these points a through car can be boarded at least every 5 minutes during the day, and for a five cent fare.

The Operation of these improved cars has had a very depressing effect on the earnings of the South Side Elevated Railway, and it is reasonable to expect that an even greater effect is felt by the Illinois Central Railroad.

The South Side Elevated Ry. has instituted an express service during the rush hour between 43rd St. and the Union loop without stop. This decreases by 5 minutes the running time from all stations south of 43rd St. into the city. This service attracts many passengers who would otherwise use the Illinois Central Railroad from Woodlawn station. The elevated road has also built a line [illegible]

suburban service of Kenwood with a terminal at 42nd Pl. and the I. C. R. R. right of way. This line competes with the 43rd St. station and Oakland station for traffic. There is provided express service from the line into the city during rush hour, and direct local service during the day. The Kenwood branch carries 6000 passengers a day from its five stations, three of which are within easy walking distance of the 43rd St. or Oakland stations of the I. C. R. R.

Table VIII shows the comparative running time to the Union Loop in the case of the S. S. El. Ry., and to Van Buren St. station in the case of the I. C. R. R. as noted for the years 1906 and 1908. This illustrates the advance of the South Side Elevated R. R. as a factor in the competitive [illegible] traffic.

TABLE VIII.

Comparative Running Times in City, I. C. R. R. and S. S. El. Ry. for 1906 and 1908

Station	I. C. R. R.		S. S. El. Ry.		
	1906 Express	1908 Local	1906	1908 Local	1908 Express
Woodlawn	18 min.	22 min.	31 min.	31 min.	27 min.
42nd Pl.		15 min.		20 min.	16 min.

In addition to the improved running times as noted in Table VIII, the South Side Elevated R. R. lands its passengers at least two blocks nearer the business district than does the Illinois Central R. R. In addition the train service is more frequent and cleaner, and the

rate of fare is 5 cents as compared with 10 cents on the I. C. R. R.

The effect of this acute competition of the street and elevated railroads is not greatly apparent at any express station, except Woodlawn, during the rush hours. For stations between Woodlawn and Hyde Park the effect is a decrease in the area from which the I. C. R. R. draws its patrons. Persons living a considerable distance from the stations now take the street railway when formerly they walked to the I. C. R. R. station.

The local service has suffered extremely from this competition. The introduction of the side door car has not seemed to make more attractive the suburban system when compared with other modes of travel. The Kenwood branch of the So. Side Elevated Ry. has taken practically all the suburban business away from Oakland and 42d St. stations. The Kenwood (47th St.) station appears to be the only station on the entire suburban local line that provides a vigorous business. The local platforms at stations from Woodlawn to Hyde Park, and also largely at Madison Park, have for a long time been filled only with those who have "just missed the express".

The competition of the surface and elevated lines is most apparent during the middle of the day. At this time the I. C. R. R. trains are operating on a 20 minute headway whereas elevated trains at 42nd St. leave on a 5 minute headway, so that from the 43rd or Oakland district it is an even chance that a passenger will arrive in the city as quick by the elevated as by the I. C. R. R. During the rush hour the service

of the elevated is almost certain to reach the city quicker. The surface lines divert a greater percentage of traffic from the I. C. R. R. during the middle of the day than they do during the rush hour. This is for the reason that the time of journey is of less importance during the middle of the day than during rush hours; and convenience, cleanliness, and frequency of service are uppermost in the mind of the patrons.

The considerations in this section are of course incomplete without tabulated figures of traffic and ticket sales; but it is believed that such figures if provided would merely indicate the degree of the conclusions noted above, rather than to controvert any of them.

SUGGESTED REMEDY.

Provided the facts are as above stated it seems advisable to undertake the complete rehabilitation of the suburban service in order to regain its former patronage and to receive the full benefit from the ever growing population along the lines.

Rehabilitation along the lines suggested below will be effective in securing the desired result.

1. Double the frequency of train service over all lines during the middle of the day.
2. Reduce rates of fare on the Woodlawn local trains to a uniform 5 cent fare.
3. Provide more rush hour trains with greater seating capacity.

4. [illegible]

5. [illegible]

The best method of obtaining these results, and in fact the only possible method with present physical limitations of terminals and locomotives, is to change the motive power of the train from present steam locomotives to electric operation by means of motors distributed throughout the train, and controlled by a multiple unit system. It will be shown that the results derived can be obtained with a motor equipment and power distribution system which is economical, reliable, and in accord with best modern practice. In addition, it will be shown that this method of operation has decided advantages as far as operating expenses are concerned which in themselves can almost be considered sufficient to recommend the adoption of an electric system. The chief argument for electric operation, however, is that it will permit amplifications of service as regards frequency of trains, speed, and cleanliness so as to cause a decided increase in traffic; -- a result obtainable by no other method except electric operation of trains.

It is necessary to establish certain working assumptions regarding the service as a whole, to be used in the investigation of the proposed electric equipment. These assumptions are considered below in detail.

[illegible]

I. Complete estimates are prepared relating to the equipment of the entire suburban service with the exception of the service to

Addison. This comprises in all [illegible]4 miles of track. The Addison service can be operated by steam over the electrified line between Van Buren St. and St. Charles Air Line Jct. The estimates are on the basis of an equipment providing a decided amplification of service such as would be required say [illegible] years after electric operation is begun. Page 81

II. In addition, there are prepared estimates relating to equipping the entire suburban service with the exception of the Addison line, but with a total car miles per annum equal to that now operated. Amplification of service as regards frequency and speed of trains is the same as for Estimate I, but the number of cars per train is decreased to accord to present requirements. Page 94

III. An estimate is prepared for the equipment of the Woodlawn local service only, – with the idea that a uniform five cent fare be instituted on this line. The peculiar advantages of electric traction would be most noticeable for this type of local service, and the installation would be advisable as preliminary to the equipment of the entire suburban service. Page 95

IV. Finally an estimate is given for the equipment of the Woodlawn local service and of the express tracks from Van Buren St. to South Chicago and Grand Crossing. These are worked out on a basis similar to Estimate I, but with the idea that there would arise no particular advantage in extending the electric zone beyond this point. Suburban passengers are to be transferred to steam operated trains at this point. Pages 96 and 97

PROBABILITY OF MORE EXTENSIVE ELECTRIFICATION.

An important question of engineering policy relating to the choice of the proper system of electric traction arises when there is considered the probability of more extensive electrification at some future date. The City of Chicago will undoubtedly bring pressure upon all the incoming railroads to operate electrically inside the city limits. In addition, certain engineers have predicted that long sections of trunk line railroad would soon be equipped with electric locomotives for freight and passenger service. Their argument is largely that of decreased operating expenses that more than warrant increased capital charges with electric equipment.

If either of these possibilities should occur in the case of the I. C. R. R., the fact should be considered in determining the best system of electric operation for the suburban service; since the system giving best results for trunk line service or for heavy terminal service, is not necessarily the one best adapted for the suburban service. If there is any reasonable assurance of future extension along these lines, it would undoubtedly be desirable to sacrifice some features of the suburban service equipment in order that there may be unity of system, and flexibility of operation, at some future date when all extensions are completed.

It is not the intention of the writer to investigate the probability of trunk line electrification or of heavy terminal electrification for the through service. As a working basis the assumption is made that the probability of trunk line electrification

is too remote in the case of the I. C. R. R. to warrant any consideration. There is some possibility of the extension of the terminal electrification of the through service with the idea of eliminating smoke nuisance; hence the system of electric traction to be adopted must be such as to be extended to this terminal service if necessary. However, the influence of this consideration on the design of suburban equipment is taken as very slight; and that system of electric traction giving best results for suburban service is assumed the proper one to use for the terminal service as well.

TYPE OF CAR

It is assumed that the standard 71 ft. multiple side door car be used for the electric service. (Fig. 71) South of Kensington where the suburban trains operate on main line tracks, the side doors will not be used since the usual ground level platforms prevail. Entrance and egress will be had by means of the usual steps at the end of each car. The traffic at these stations is comparatively light, and the absence of the side door principle will have but little effect on the duration of station stops. The arguments in favor of this type of car on the steam local runs have been noted and its adoption seems advisable for the entire electric service. It is practically a fire proof car, a desirable feature when electric apparatus is used. The adoption of this type permits the equipment of the present side door cars with electric motors and apparatus to convert them into standard electric suburban cars. The objection to adopting this type of car is that platforms at Cheltenham, South Shore and Blue Island must be relocated since the side door cars demand

well be loaded on a curved platform with a curvature exceeding 3 degrees.

Certain changes in construction of the side door cars are necessary to adopt it for electric operation, but these are of a minor nature.

TRAIN OPERATION.

This study is based on the operation of side door cars in trains equipped with motors throughout the train, the whole controlled by one motorman by means of multiple unit control. This is the universal practice of elevated and subway railways, and is followed by the electrified suburban lines of the New York Central, Long Island, West Jersey and Sea Shore Railways, etc.; and by all interurban railways that operate cars in trains. The advantages of this method as compared with operation by electric locomotives are briefly as follows: -

1. Increased rate of acceleration due to greater weight available for adhesion.
2. Decreased total train weight.
3. More efficient terminal service.
4. Increased motive power proportionate to increase of length of train.
5. Less wear on track due to distribution of weight.
6. Permits the use of one and two car trains to be run economically during slack hours.

In order to provide interchangeability of suburban equipment it is necessary that all motor cars shall have indentical equipment as regards motor equipment and gear ratio.

MAXIMUM SPEED.

The maximum speed of the present express trains on the run from Van Buren St. to Hyde Park is about 45 M. P. H. It is necessary to increase this speed to 50 M. P. H. in order to produce the desired improvement in the schedule time for this particular run. It is apparent from this that no equipment can be considered unless it will propel a train at about 50 M. P. H. on straight level track. This maximum speed is about typical of American suburban trains when electrically operated. The six car trains of the New York Central R. R. operating in the New York electric zone, are geared for about this maximum speed. The Long Island Ry. electric suburban trains will operate at 45 M. P. H. The West Jersey and Sea Shore R. R. trains however operate at 60 M. P. H. speeds.

COASTING. BRAKING. DURATION OF STOP.

The method of determining power and speeds used in this study is on the basis of a small amount of coasting from the time of shutting off power to time of applying brakes. The amount is but 5 to 10 seconds depending on the length of run. In addition 5 % of the time time determined is added to obtain the time table schedule time.

The rate of retardation during braking is assumed at 1.6 M. P. H. per sec. This corresponds to 7.3 % of train weight adhesion.

The length of stop is assumed to be 12 seconds at all stations except Van Buren St. where 20 sec. is allowed. Extended observations have shown these to be conservative values for trains of side

door cars.   In addition to regular station stops, there is proposed a 15 sec. stop at the Combination station at 149th St. for all [illegible] trains, both north and south bound.

TRAIN RESISTANCE.

Information regarding train resistance at constant speed is necessary to properly determine the ultimate maximum speed as well as the instantaneous rates of acceleration at any lower speed.   Very satisfactory data is available at the present time regarding train friction of electrically operated trains.   Tests conducted by the N. Y. C. & H. R. R. R. and the Interborough Rapid Transit Co. are particularly noteworthy as applying to the present instance.   Fig. 8 shows train friction deduced from data of A. H. Armstrong for trains of varying numbers of cars of multiple side door type when loaded and equipped to weigh about 35 tons each.

The actual maximum speeds are seen to be 56 M. P. H. for a 5 car train, to 47 M. P. H. for a one car train; when each car is equipped with 2 GE 69 B motors per car, gear ratio 2.46 with 36 in. wheels at 570 volts.   According to the curves, a 5 car train will make the run in less time than will a one car train; but the tendency to prolong station stops with a long train balances the decrease in running time. For the purposes of this study it is sufficient to assume one friction curve as representing the train resistance per ton for any length of train; and to be on the safe side, a conservative set of values is chosen, as plotted by the heavy line of Fig. 8.   All speed and energy determinations throughout the entire study are made on the basis that this curve expresses the train resistance.

SYSTEMS OF TRACTION AVAILABLE.

The application of electricity as a motive power is possible by various methods. Those appearing most worthy of investigation for the I. C. R. R. suburban service are listed below: -

1. Direct current 600 volt 3rd Rail System.
2. Direct current 600 volt 3rd Rail System using forced ventilated motors.
3. Direct current 1200 volt 3rd Rail System using forced ventilated motors.
4. Single Phase alternating current 25 cycles 9000 volt trolley.

The first system, the direct current 600 volt 3rd rail, is in extensive use by elevated and heavy interurban railways, and by steam railroads whose service closely approximates that of the I. C. R. R. suburban service. The system has been developed to a high degree of engineering excellence, and its reliability and adaptability for the service proposed has been fully demonstrated. In the following table is given a list of steam railroads now using this system together with their present extent of electric equipment.

TABLE VIII.

List of Steam Railroads Using the 600 Volt Direct
Current 3rd Rail System for Operationg
Suburban and Main Line Service.

Name of R.R.	Service	Miles of track	No. Motor Cars	Max. speed M.P.H.
N.Y.C. and H.R.	New York Electric zone	292	135	50
West Shore R. R.	Utica-Syracuse line	106		[illegible]
Long Island R. R.	Atlantic Ave. suburban lines	105	[illegible]	45

Name of R. R.	Service	Mi. of Track	No. Motor Cars	Max. Speed M.P.H.
West Jersey & Sea Shore R. R.	Camden–Atlantic City	[illegible]	[illegible]	60
Northwestern Pacific R. R.	Sausalito–San Rafael	[illegible]	[illegible]	50
Metropolitan Ry.	London–Uxbridge suburban	60		46
Metropolitan Dist. Ry.	Suburban lines London	105		40
Northeastern Ry.	Newcastle–Tynemouth	82		46
Great Western Ry.	Hammersmith & city	14		40
Lancashire and Yorkshire	Liverpool–Crossens	49	[illegible]	46

The 1200 volt direct current system is used at present by several interurban railways, and is proposed for use with 3rd rail on the California Midland R. R. The Southern Pacific R. R., Oakland–Alameda suburban lines, are at the present time being equipped to use this system with current supplied from overhead trolley.

The 25 cycle single phase alternating current system is prominently used by the N. Y. N. H. & H. Woodlawn–Stamford line and by the Erie R. R., Rochester Mt. Morris branch. If this system be used at Chicago 9000 volts would be the proper value of trolley potential since an extensive 9000 volt system already exists owned by the Commonwealth Edison Co., with which common frequency tie lines would be desirable. Abroad, this system has been recently applied to the London Brighton and South Coast R. R. suburban lines, and to the Midland R. R., Morecambe–Heysham–Lancaster line. In Germany and Austria it has been adopted as the system to use for various main line electrification projects well under way.

In the present instance, there are many practical difficulties in the way of an overhead trolley construction chief of which is the [illegible], [illegible], [illegible] effectually [illegible] St. north. On the [illegible] between [illegible] St. and [illegible] St., the [illegible] and [illegible] of a single supporting span; and a [illegible] would be necessary. The whole appearance of the work would lack the unity that characterizes the New Haven installation.

On the other hand [illegible] for a third rail [illegible] all types of hopper cars of which the [illegible]; [illegible]. Further, the [illegible] of a relatively great number of trains, and the influence of cost of car equipment is liable to be predominant as compared with cost of transmission system.

These considerations point to the probability of a direct current [illegible], although it may [illegible] alternating current system, the disadvantages noted above could probably be satisfactorily [illegible].

[illegible]

The [illegible] a method of determining the proper system of electric traction to be used as follows: A complete study is made on the basis that the [illegible] volt third rail system be used

and cost estimates and operating schedule worked out. A comparative estimate is then made for the 1200 volt system and alternating current system on the basis that equipments operating by these methods must equal the performance of the 600 volt 3rd rail system as far as speed is concerned.

The advantage of this method of comparison is that all the operation calculations are made relating to that system of traction which appears at first thought to be most adaptable for the service; and if further investigation corroborates this fact, considerable of the actual engineering work associated more with construction than with preliminary reports will have been completed.

[illegible] 600 VOLT.

An ordinary means of determining the details of car equipment and power requirements in a project of this nature is to assume at the beginning a certain operating schedule of train service to which the electric trains must run. In some cases it is necessary that the best present steam service be duplicated; and in others that decided increase of schedule speed be provided ~~for~~, on account of a competing railroad's schedule. In the present instance there is no such rational method of fixing at the outset a desirable schedule speed by which electric trains are to operate. The only consideration is that the schedule speed be 20 % or more greater than at present. (See page 28).

The matter is so closely related to the motor equipment and operating energy costs, that it is advisable to postpone the presentation

of a working or provisional schedule that will furnish the basis for cost estimates until uncertainty regarding the speed possibilities of various sizes of motor equipments, are determined.

TYPICAL RUN

As preliminary to the study of motor equipment, it is desirable to determine the length of average run; the performance of which in service, by trains having various motor equipments will furnish an estimate of their relative performance over the various regular trips in suburban service. It is shown later than the results obtainable for this typical run can also be used to express the absolute values of energy and speed as they will occur in service.

The average length of run is not equal to the average distance between stops, except for the simple case of one type of service only; but is affected by the number of cars per train and frequency of service on different portions of the road. In general this figure is expressed thus:

$$\text{Length Average Run} = \frac{\text{Total car miles per average day}}{\text{Total car starts per average day}}$$

For the I. C. R. R. suburban service, the typical run calculated in this manner is 0.815 miles. It is assumed that this value will hold for the electric service as well, since amplification of service will be proportionately divided among the different classes of runs.

The argument in using this typical run is merely that the particular motor equipment that will give best continuous performance on this average run of .815 miles, will give best results on the mixed service

of the actual road. There are many precedents that this is an allowable assumption, and it is a method in general use for determinations of this kind.

MOTORS OF 600-VOLT D.C. SYSTEM.

There is no single item upon which so much depends the future working of the electric system as upon the railway motor. It is the means of connecting the electric system with the train propulsion and upon its characteristics depend the performance of the train as regards speeds and of the electric system as regards power requirements, which in turn determine all details of distribution and power generating system.

Appendix A contains a tabulation of the types of motor equipment as used on various railroads employing the 600 volt direct current system, together with other significant data regarding the characteristics of the equipment.

Appendix B contains an extended discussion of the possibilities of motor equipments of various sizes when considered for the present case, and discusses the reasons for adopting the particular size of motor and rate of initial acceleration as employed in these calculations for the 600 volt direct current system. From this, it is evident that it is necessary to provide motor equipment aggregating about 400 horse power in motors (one hour rating) per side door car. This can be furnished by two nominal 200 HP motors of standard design per car, and having all cars motor cars. The cost of equipping all cars as motor cars is no greater than that of dividing them up into one half trailers and one half motor cars, but with twice the equipment per motor car. The shop and

inspection charges are greater if all cars are motor cars, but the resulting convenience in making up trains fully warrants this extra charge.

The motor upon which are based all calculations for the 600 volt 3rd rail system with motors cooled by natural ventilation is the G E 69, 200 H.P. railway motor. The reason for choosing this particular motor was that extended data regarding its characteristics etc. was available. It is one of the most modern motors in use; but specifications for motors based on the results of a study of this G E 69 motor can acceptably be met also by the Westinghouse Electric and Mfg. Co. with some form of their No. 112 motor, or by either company with a similar motor having interpoles. The use of interpoles for this class of service is desirable but complete data on these large interpole motors has not been issued. They are able in every respect to duplicate the performance worked out on the basis of the G E 69 motor; and in addition offer some features providing extremely low maintenance that make profitable their purchase at a higher first cost.

THE G E 69 RAILWAY MOTOR.

This motor was designed for the Interborough Rapid Transit subway and the sample motors tested were the G E 69 A type. When the contract was filled certain slight structural changes were provided, the motor supplied being designated the G E 69 B type. Later this same motor was furnished the Metropolitan District Ry. and other tube and suburban railways in London. Fig. 9 shows the dimensions of this motor. Fig. 10 shows characteristic curves at 570 volts. Fig. 11 shows the general speed tractive-effort curve, the extreme utility of which is

Shown in an article by the writer "Method of Speed Time Curves", Street Railway Journal Feb. 9, 1907. Fig. 12 shows core loss curves and Fig. 13, a complete thermal characteristics from which the heating of the motor in service is estimated.

DETERMINATION OF GEAR RATIO—G E 69 B MOTOR.

Appendix B shows that the proper rate of initial acceleration to give maximum schedule speed for a run of .615 miles is 1.1 m.p.h. per sec. providing accelerating current corresponds to full load one hour rating. However since appendix B is worked out on the basis of a certain standard direct current motor, it is best to recalculate the results again employing the G E 69 B motor characteristics, and in addition make more precise heating estimates than are found in appendix B. Typical runs with various gear ratios are shown in figs. 14 to 17 incl. Fig. 18 shows results obtained from these curves as regards schedule speed, energy consumption, and motor heating. From Fig. 18, it is evident that the maximum schedule speed is provided with the gear ratio 2.22,-with an initial acceleration of 1.10 M.P.H. per sec. However consideration of motor heating sets the gear ratio at 2.46,-the value used for speed and energy calculations. This provides a maximum speed of 50 M.P.H., the lower limit as set by previous considerations. If it were not for this necessity for a 50 M.P.H. maximum speed, a lower gear ratio would be adopted since the temperature rise with the 2.46 gear ratio (65 degrees Cent.) is about the upper limit, and lower operating temperature would be perhaps desirable.

[illegible] Railroad suburban cars and to the West Jersey and Sea Shore R. R., while a modification of the G E 69 B motor, is not adapted to the I. C. R. R. suburban service on account of the short length of typical run. The matter is considered in some detail in appendix C.

The curves of Figs. 14 to 18 incl. are based on a three car train made up of side door cars each of which weighs loaded 58.75 tons,- as follows:

TABLE III.

SIDE DOOR CAR WEIGHT, 600 VOLT, 3rd RAIL SYSTEM.

G E 69 B MOTORS.

Side door car body with lights and heaters,	58900 lbs.
Motor truck 7'- 6" wheel base with 36" steel wheels,	15000
Trailer truck,	11000
2 - G E 69 B motors complete,	12400
[illegible]	[illegible]
Air Compressor and new brake rigging etc.	1600
weight light	102500 lbs.
100 Passengers at 150 lb.	15000
weight loaded	117500 lbs.
Add for inertia rotating parts	9100
equivalent weight	126600 lbs.

[illegible]
[illegible]

In all speed time curves to follow, on which are based data on time of run, energy consumption etc. for various suburban runs, a certain method of handling the controller during the accelerating period is assumed. This consists in allowing the motors to accelerate on the series motor curve for a short length of time before they are connected in parallel with resistance. This method of operating decreases the schedule speed for the typical run by 1 per cent but decreases the energy consumption by 8.5 per cent due to the lessened rheostatic losses; and fully warrants the adoption of this method of control. Fig. [illegible] shows the type run with this modified method of acceleration. This method can be performed automatically by means of an attachment to the limit switch and produces but slight complication of control apparatus.

The entire matter is considered in some detail in Appendix D where complete curve sheets and calculations are shown.

An advantage of this method is that it furnishes a simple way of making up lost time by merely disconnecting the limit switch series trip and letting motors accelerate in the regular manner. This however is at the expense of considerable motor heating, since the values of resistance in series with motors, in parallel, are much lower than would be the case if a limit switch trip were not provided. See Appendix D

[illegible]
[illegible]
600 VOLT [illegible]

The profile and alignment of the I. C. R. R. suburban tracks is such that it is not necessary to calculate detailed speed time curves for each particular run of a train in service. Such calculation is only warranted where the grades are heavy, and curves are such as to necessitate slow down and re-acceleration. There are no such curves in the I. C. R. R. suburban district. The assumption on which these results are based is that the track is level tangent throughout. Such an assumption even on roads of very rugged profile is allowable, and gives results that check very closely with results based on an accurate speed time curve study of the various runs. (a)

All calculations are based on the results of a study of a three car train with weight according to Table IX. Train friction is assumed according to Fig. 8. The power input is proportioned directly as the number of cars per train,- unit values being obtained from a study of a three car train.

Fig. 25 shows the General Run Sheet or speed-time curve of a three car train on tangent level track. Curves of power input and motor losses are included. This curve is conveniently divided up into runs of various time durations as shown by the braking curves. The results for each run as regards distance run, energy consumption, average power,

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(a) L. B. Stillwell and H St. C. Putnam. Electric Motor vs steam locomotive. Proc. A.I.E.E. page 241, 1908, gives actual comparisons of results worked out by both methods on a road of rugged profile.

input, and motor losses, are found. The data is then replotted with distance run as a base and is shown in Figs. 26, 27, and 28. These figures show immediately the results of operation over a run of any distance; and applying them to the various runs of the I. C. R. R. suburban service, Table X of Individual Run Data is compiled. From Table X, Table XI is compiled which provides data regarding the various trips in the mixed suburban service. There is added 6 % to the time of each run as obtained from Table X to obtain the total trip time. This provides necessary leeway for making up time. Items from E to I of Table XI are calculated on the basis of a five minute lay-over at the end of each trip.

TABLE X

[illegible]

G E 69 B MOTORS - FROM FIGS 26 TO 28

	A	B	C	D	E	F
RUN	Time for Run not incl. stop Seconds	Time for Run Incl. stop Seconds	Kilowatt Hrs. per car 570 volts	Avg. K.W. per car 570 volts Time B	Watt Hrs. Field loss per motor	Watt Hrs. armature loss per motor
Randolph-Vanburen	1:32	2:02	3.5	[illegible]	[illegible]	[illegible]
Van Buren-Park Row	1:30	1:42	[illegible]	[illegible]	[illegible]	[illegible]
Park Row- 16th St.	1:26	1:38	3.3	108	[illegible]	70
16th St. 22nd St.	1:25	1:37	3.25	120	[illegible]	74
22nd St. 26th St.	1:15	1:27	3.0	[illegible]	[illegible]	64
26th St. 31st St.	1:27	1:39	3.3	120	[illegible]	76
[illegible] Douglas	1:28	[illegible]	[illegible]	[illegible]	[illegible]	75
Douglas Oakland	1:13	1:25	2.8	125	26	52
Oakland 43rd St.	1:30	1:42	3.4	120	[illegible]	[illegible]
43rd St Kenwood	1:29	1:41	3.4	120	30	78
Kenwood -Madison Pk.	1:09	1:21	2.65	114	27	[illegible]
Madison Pk.-Hyde Pk.	1:04	1:16	2.4	114	[illegible]	[illegible]
Hyde Pk.-SouthPk.	1:20	1:32	3.05	[illegible]	[illegible]	[illegible]
South Pk.-60th St.	1:12	1:24	[illegible]	[illegible]	[illegible]	[illegible]
60th St.-Woodlawn	1:11	1:23	2.75	120	27	[illegible]
Woodlawn-67th St.	1:20	1:32	3.05	120	29	69
67th St.-Brookdale	1:06	1:18	2.5	116	[illegible]	[illegible]
Brookdale-Essex	0:50	1:02	1.9	[illegible]	[illegible]	38
Essex- Grand X	1:20	1:32	3.05	120	[illegible]	69
Grand X-Drexel	1:48	2:00	4.0	[illegible]	[illegible]	[illegible]
Drexel-Woodruff	1:24	1:36	3.2	[illegible]	29	72
[illegible]	1:17	[illegible]	[illegible]	120	[illegible]	66
Dauphin Pk.-Burnside	1:36	1:48	3.6	120	31	[illegible]
Burnside-104th St.	2:13	2:25	4.9	[illegible]	[illegible]	120
104th St.-Pullman	1:52	2:04	4.2	[illegible]	31	[illegible]
Pullman-Kensington	1:25	1:37	3.25	120	30	74
Kensington-Wildwood	3:07	3:19	6.6	119	49	160
Wildwood-Riverdale	1:58	2:10	4.4	[illegible]	[illegible]	104
Riverdale-147th St.	3:06	3:18	6.55	119	[illegible]	[illegible]
147th St.-Harvey	2:06	2:18	4.7	[illegible]	34	111
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	41	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	120	37	[illegible]
Homewood-Flossmoor	2:46	2:58	5.9	[illegible]	[illegible]	140

TABLE X (Cont.)

	A	B	C	D	E	F
Run	Time for Run not incl. stop Seconds	Time for Run incl. stop Seconds	Kilowatt Hrs. per car 570 volts	Avg.K.W. per run 570 volts Time B	Watt Hrs. Field loss per motor	Watt Hrs Armature loss per motor
Van Buren-Comb.Sw.	1:38	1:50	3.7	121	31	[illegible]
Comb.Sw. Hyde Pk.	6:59	7:11	1[illegible].2	110	[illegible]	[illegible]
57th St. Parkside	1:39	1:51	3.7	120	31	57
Parkside Bryn Mawr	1:20	1:32	3.05	119	[illegible]	69
Bryn Mawr So. Shore	1:21	1:33	3.1	120	29	75
So. Shore Windsor Pk.	1:35	1:42	3.4	120	30	79
Windsor Pk. Cheltenham	1:35	1:47	3.6	121	31	85
Cheltenham 83rd St.	1:15	1:27	2.85	118	28	44
83rd St. 87th St.	1:28	1:40	3.35	120	27	[illegible]
87th St. South Chgo.	1:18	1:30	3.0	120	[illegible]	[illegible]
[illegible]	2:02	2:14	[illegible]	[illegible]	[illegible]	100
Stewart Ridge-State St.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	59
State St.-W. Pullman	1:25	1:37	[illegible]	[illegible]	29	74
Pullman-Plano	1:14	1:26	[illegible]	116	28	[illegible]
Plano-Ashland Av.	1:31	1:43	[illegible]	[illegible]	[illegible]	[illegible]
Ashland Ave.-Burr Oak	1:32	1:44	[illegible]	[illegible]	[illegible]	82
Burr Oak-Blue Island	1:31	1:45	[illegible]	[illegible]	[illegible]	[illegible]

TABLE XI

TOTAL TRIP DATA – COMPILED FROM TABLE X

		Woodlawn Local Trip	South Chgo. Express	Blue Island Express (A)	Grand X Express	Blossmoor Express (a)
A	Time for trip min. and sec. (+) 5%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 10sec.
B	Schedule speed MPH	19.7	24.6	24.0	26.7	26.6
C	Average K.W. per car	124	121	122	121	121
D	Watt Hrs. per ton mile	128	92	98	87	88
E	Average Field loss per motor-watts	864	765	820	695	760

TABLE XI (cont.)

	Woodlawn Local Trip	South Chgo. Express	Blue Island Express (a)	Grand X Express	Flossmoor Express (a)
F. Average armature loss per motor—Watts	2070	2520	2410	2220	2520
G. Ratio of Distribution	2.40	3.05	2.95	3.30	3.20
H. Temp. Rise Deg. Cent. Fields	57	59	62	54	60
I. Temp. rise Deg. Cent. Armature	60	64	67	63	67

(a) [illegible]

PROVISIONAL SCHEDULE

There is provided in Tables X and XI sufficient data on running times to lay out the new schedule for electric service. This new schedule is the basis for determining the magnitude of power generating and distribution systems. This provisional schedule is shown in detail in Figs. 29 to 40 in a semi graphic manner. The various trains are numbered, and also the number of cars per train is shown. The time of arrival at any station can be obtained by using these sheets in connection with the running times of Table X.

This schedule provides for a 154 per cent increase in seat miles, a 76% increase in the number of trains, and a 50% increase in car mileage, as compared with the present operating schedule with steam service. The

endeavor has been made to provide a running schedule, and the high schedule speed permits a method of operating with short lay-overs that provides a maximum car-miles per day for any number of cars. It is believed that the schedule is workable, that is, it does not leave cars unused at night at different points from which they started. The Woodlawn local service has been arranged with the idea of instituting five cent fare on that portion of the line.

Figs. 41, 42, and 43, show the total car movement at Randolph St. terminal. The maximum train movement occurs during the hour from 5 to 6 P. M., during which 148 cars enter or leave the terminal. The minimum headway is 2 1/2 minutes from Randolph St. during the rush hour. Five car trains are assumed during rush hours in the direction of heaviest travel. This limiting length is due to the present length of station platforms.

Fig. 44 shows the complete provisional schedule for week day service in the form of a graphic time table. This is used for determining generating station, feeder, and substation loads.

The provisional schedule as worked out is estimated to be sufficient for the next five years hence, provided the electric system is operated with five cent fare for the Woodlawn local service, and that the frequency of trains is as given in this schedule. It is assumed that up to this time, the schedule will be operated exactly as indicated herein, except that the number of cars per train be decreased to conform to present traffic conditions. The advantages of frequent train service are so extremely important in attracting patronage, and since

frequency of service is so easily and cheaply obtained with an electric system, it would be a great mistake to consider curtailing the initial electric service in this respect.

Certain changes in the operating methods of the suburban service are advisable to provide less dead mileage and shorter lay-over time than would be the case if the electric trains were operated in the same manner as at present. These are considered in the following paragraphs, which relate to the electric train service for the various suburban runs.

FLOSSMOOR EXPRESS TRAINS. ELECTRIC SERVICE.

Total time for run 56 min. all stops   Lay-overs [illegible] to [illegible] min.

Regular service:- Leaves Randolph St. on the hour except at 2:00 and 3:00 A. M. Two trains operating.

Train 1 starts 4:00 A.M. Randolph Stops 1:56 Randolph
Train 2 " 5:00 " " " 2:56AM "

Rush Hour Service:- 3 car Trains.

Leave Flossmoor 8:27A.M. Leave Randolph 5:45 P.M.

BLUE ISLAND EXPRESS TRAINS-ELECTRIC SERVICE

Total time for run 46 min. all stops Lay-overs, 5 min. Randolph,
14 min. B. I.

Regular service:- Leave Randolph on the half hour except at 5:30 A.M. and [illegible] A.M. Two trains operating.

Train 1 starts 4:39 A.M. Blue Island. Stops 1:16 A.M. Blue Island
2 " 5:39 A.M. " " " 2:16 A.M. " "

Rush Hour Service:- 3 car Trains
Leave Blue Island [illegible] A.M. Leave Randolph [illegible] P.M.

SOUTH CHICAGO AND GRAND CROSSING EXPRESS-ELECTRIC SERVICE

This service is composite. A train runs alternately, first to South Chicago and return and then to Grand Crossing and return and repeat. This enables a complete double round trip to be made in two hours and results in a minimum number of trains being required for this service.

South Chicago- Total time for run 31 1/2 min. 4 min. lay-overs
Grand Crossing-Total time for run 21 min. 4 min. lay-overs

Regular service:- Leaves Randolph St. 10 min. and 40 min. after the hour to South Chicago, and [illegible] min. and [illegible] min. after the hour to Grand Crossing. Four trains operating.

Train 1	starts	7:10 A.M.	Randolph	Stops	[illegible]	Randolph
2	"	7:14 A.M.	Grand X	"	9:12 P.M.	Grand X
3	"	10:10 P.M.	Randolph	"	9:15 P.M.	Randolph
4	"	7:14 A.M.	South Chgo.	"	7:11 P.M.	South Chgo.

Rush hour service:- See following pages on Rush Hour Service.

[illegible] LOCAL TRAINS - ELECTRIC SERVICE

Total time for run 24 min. Lay-overs 6 minutes

Regular Service:- Leaves Randolph St. 7 1/2, 22 1/2, 37 1/2, and 52 1/2 minutes after the hour. Four trains operating.

Train 1	starts	7:07 1/2 A.M.	Randolph	Stops	[illegible]	Randolph
2	"	6:22 1/2 A.M.	"	"	1:17 1/2 A.M.	"
3	"	6:37 1/2 A.M.	"	"	[illegible]	"
4	"	6:52 1/2 A.M.	"	"	12:47 1/2 A.M.	"

Rush hour service:- To give 5 minute headway northbound from 7:05 A.M. to 8:55 A.M. and southbound from 5:12 P.M. to 6:32 P.M. See following.

RUSH HOUR SERVICE - ELECTRIC OPERATION.

Certain data has already been provided relating to rush hour service. The rush hour trains are operating as extras and do not interfere with the regular train schedule. These extras provide service according to the provisional schedule and after making a run are dispatched immediately and [illegible] back to terminal to make another rush hour trip. That is, most rush hour trains make two and sometimes three paying trips during any rush hour. The manner in which this is accomplished during the A.M. rush hour is indicated in the Table XII following. [illegible] method of operating these trains.

NUMBER OF CARS REQUIRED FOR PROVISIONAL SCHEDULE.

For the regular trains, the maximum number of cars operated during the rush hour, at which time each train is composed of five cars is 60 as follows:- Woodlawn Local 20, Flossmoor Exp. 10, Blue Island Exp. 10, So. Chicago and Grand Crossing Exp. 20.

For the rush hour trains operating according to the method of Table XII, there is to be provided 45 cars. The total number of cars necessary for the provisional schedule is therefore 105. It is reasonable to suppose that owing to needed heavy repairs, 5 cars may not be available during a rush hour. However all light repair, inspection, and cleaning can be arranged for between rush hours.

It is necessary to provide then 110 multiple unit side door cars to satisfactorily perform the service according to the provisional schedule of 154 % greater seating capacity than present steam service.

TABLE XII

[illegible]

Trains listed in the order of their arrival at Randolph St.

Leave		Arrive	
Woodlawn	7:03 A.M.	Randolph St.	7:27 A.M.
"	7:13	"	7:37
"	7:18	"	7:45
So. Chicago	7:19	"	7:50
Woodlawn	7:28	"	7:52
"	7:35	"	7:07
Grand X	7:39	"	8:00
Blue Island	7:31	"	8:07
So. Chicago	7:39	"	8:10
Woodlawn	7:43	"	8:12
Grand X	7:59	"	[illegible]
Woodlawn	7:58	"	8:22
Woodlawn	[illegible]	"	8:37
Grand X	8:19	"	8:40
Woodlawn	8:18	"	[illegible]
So. Chicago	8:19	"	8:50
Woodlawn	8:28	"	8:52
"	8:33	"	8:57
So. Chicago	8:39	"	9:10
Flossmoor	8:27	"	[illegible]

COMPARISON OF [illegible] FOR [illegible] SERVICE WITH PRESENT STEAM SCHEDULE

As a further comparison of the electric service based on the provisional schedule, with the present steam service for summer week days there is prepared Table XIII below, which is to be compared with Table II page 14.

TABLE XIII.

	Woodlawn Local	So. Chgo. Express	Blue Id. Express	Flossmoor Express	Grand X Express
Randolph St. to	Woodlawn	So. Chgo.	Blue Id.	Flossmoor	Grand X
Distance miles	7.9	12.9	16.9	24.9	9.5
Time minutes	24	31 1/2	47 (a)	56 (a)	21 1/2
Number of stops	15	14	25 (a)	21 (a)	9
Length average run miles	0.55	0.92	0.82 (a)	1.20 (a)	1.05
Schedule Speed M.P.H.	19.7	24.6	24.0 (a)	26.6 (a)	26.7
Number of trains per day each way	94	39	19	19	39
Headway minutes during midday	15	30	60	60	30
Headway minutes during rush hour	5	15	30	30	15

Express headway to 63rd St. Midday 10 minutes

Express headway to 63rd St. Rush Hour 5 minutes (two of 2 1/2 min.)

Total trains operating each way per day [illegible]

Note: (a) means stops at all stations south of 63rd St.

The car mileage for the provisional schedule totals 16360 per summer week day, distributed according to the following Table XIV.

TABLE XIV.

DISTRIBUTION OF CAR MILEAGE - PROVISIONAL SCHEDULE. WEEK DAY CAR MILES.

	Operating	Dead	Total
Woodlawn Local	4030	395	4425
South Chicago Express	3130	260	3390
Blue Island Express	2840	0	2840
Flossmoor Express	3710	0	3710
Grand Crossing Express	2300	195	2495
Total car miles	16010	850	16860

Assuming a Sunday and Holiday car mileage equal to 60 % of week day, there will be operated per annum 5,890,250 car miles.

This is a very high car mileage to expect to obtain in suburban service with 119 cars, when it is considered that about one half of the cars are provided only for rush hour service. It means each car will average 49500 miles per year or 137 miles per day. However the ability of an electrically equipped car to perform such service with reasonable maintenance charge is unquestioned.

RECALCULATION OF LENGTH OF TYPICAL RUN.

At an early point in this study (page 39) it was calculated that the length of typical run for the present steam operated suburban service is 0.815 miles. The length of typical run for provisional schedule of electric service is,

$$\frac{\text{Car miles per day}}{\text{Car starts per day}} = \frac{16860}{19600} = 0.860 \text{ miles}$$

[illegible]

The proposed location of substations is shown on the diagram of 600 volt distribution Fig. 45. They are situated as follows:

Sub station No. 1 12th St. ---------------- 3.1 miles
2 Oakland ---------------- 3.3 "
3 Woo[illegible] ---------------- 4.1 "
4 [illegible] ---------------- [illegible] "
5 [illegible] ---------------- [illegible] "
6 [illegible]
7 Windsor Park

The actual locations are to be provided as near as practicable to these points. With this location, the voltage at train will in no case be less than [illegible] volts during acceleration, even during heaviest rush hour period. This assumes an average voltage of 650 at sub stations (convertors compounded 650 - 600 volts) ; 80 lb. special rolled 3rd rail with conductivity .040 ohms per mile; 3rd rail tied together at intermediate points through fuses or circuit breakers as per diagram Fig. 45. The investigation of sub station location from standpoint of Kelvin's Law of energy loss has not been made in this case. In all similar cases of which the writer is aware, consideration of allowable voltage drop made it necessary to place sub stations nearer together than was shown to be desirable by Kelvin's Law. For this reason allowable voltage drop is made the controlling factor.

[illegible]

Sub station apparatus is chosen with reference to average loads and to maximum swings. The former are of such duration (1/2 hour or

so to affect operation of convertors by causing overheating, the latter while lasting only 10 to 30 seconds cause commutation difficulties.

The sub station loads due to the operation of trains according to the provisional schedule is shown for both winter and summer [illegible] operation in Figs. 46 to 59 incl. There is also included on each load curve an estimate of maximum 10 sec. swing, assuming car lights and heaters operating. In calculating these load curves, there is assumed an average drop of voltage from car to sub station of 60 volts, the average volts at sub station being 650. Calculation of several instances taken at random has shown the fairness of this estimate. Appendix E discusses the determination of these sub station load curves.

Some of the results in the Figs. 46 to 59 are recapitulated in [illegible]

TABLE XV

[illegible] ACCORDING TO PROVISIONAL SCHEDULE.

Sub station	Average Midday	K.W. at 650 Volts A.M. Rush	P.M. Rush	Max. 20 sec. swing	24 hr average
No. 1 12th St	1015	2760	3120	9100	1170
2 Oakland	860	2970	3550	7500	970
3 Woodlawn	1100	2620	3620	7900	1048
4 Burnside	500	1020	1160	5200	485
5 Riverdale	290	750	640	4500	290
6 Homewood	180	370	490	2300	160
7 Windsor Park	310	970	740	4600	325

Modern standard design rotary convertors are capable of carrying 200 % overload for 30 seconds. On this basis there is to be pro-

plied at the various sub stations, the following rotary convertor equipment. In each case one spare unit is included.

Sub. Sta. #	1	12th St.	4 - 1000 K.W.
"	2	Oakland	4 - 1000
"	3	Woodlawn	4 - 1000
"	4	Burnside	3 - 1000
"	5	Riverdale	3 - 1000
"	6	Homewood	2 - 1000
"	7	Windsor Park	3 - 1000
		Total K.W.	23000 K. W.

At sub stations 1, 2, and 3, maximum average load during any half hour determines the equipment. At other sub stations maximum swing determines size of units. The particular size of rotary convertor adopted, 1000 K.W. will give best results for all day operation according to the sub station load curves. They are adopted for the outlying sub stations, where 750 K.W. units might suffice on account of the desirability of having uniformity of apparatus. The extra reserve may be valuable for handling special excursion trains, etc.

The preceding discussion has been with the idea that storage batteries shall not be used in sub stations. An extended study of the applicability of storage batteries in this case (See Appendix F) has shown that they are not desirable from an economic standpoint; but that in the event of future extensions to the main line tracks in the electric zone, the additional load thus occasioned can best be handled by the addition of a comprehensive storage battery equipment to the then existing sub stations.

TOTAL OUTPUT. 600 VOLT SYSTEM.G E 69 B MOTORS.

From the sub station load curves it is possible to determine the load curve and total output for the entire system with trains operating according to the provisional schedule. This total output curve is shown in Fig. 60. The curve marked "traction only" is taken from sub station summer load curves. The following are some of the items used in obtaining the values of other loads:-

Car lights per car 20-16 CP lamps at 60 watts 30-32 CP " " 120 "	3.2 Kw
Car auxiliaries, per car Pump motor (average) 1.5 Kw Control (average) 1.0 Kw	2.5
Heaters, winter only per car	15.0
Converter and Transformer losses (avg. 5.75 %)	
Feeder losses calculated on 400 Kw at [illegible] load Load Factor .38 Loss Factor .19	
Passenger and Sub Sta. lighting (60~) from motor generator at 26th St.	400
Blowers and signal system.	120

The total winter week day load is 151,200 K.W. hrs. The total summer week day load is 125,600 K.W. hrs. Assuming .6 week day load for holidays and [illegible] weeks of winter load and [illegible] weeks of summer load; the total output per annum is 46,485,000 K.W. hrs. from power house.

COMPARISON OF ENERGY REQUIRED PER CAR MILE AS OBTAINED FROM LOAD CURVE AND FROM TYPICAL RUN CURVE

The total output per car mile at 3rd rail, for traction only is 4.94 K.W. hrs. per car mile; as determined from knowing total car miles operated and total energy for traction according to Fig. 60. This is

a satisfactory agreement with the value obtained for a typical run of .86 miles (see page 56) which is 4.35 K.W. hrs. per car mile.

It follows then that in the comparison of other systems of traction with the direct current 600 volt system on the basis of energy consumption, it will be sufficient to use for the value of kilowatt hrs. per car mile the value obtained from a typical run curve. Also the absolute values so obtained may be used to determine total output with these other systems of electric traction.

[illegible]

It is assumed that the railroad company has a right to erect a pole line along its right of way to the towns in question. Transmission of power at 33,000 volts [illegible] lines is [illegible]. This is standard operating condition of the Commonwealth Edison Co. for its output when transmitting. The transmission layout with lines and cables supplying the 600 volt DC system is shown in Fig. 62.

The arrangement provides for duplicate feeding throughout with sectionalized bus bars so that one or more independent lines can be run through to any sub station. The use of 2/0 cables is assumed for these lines. The total miles of 3 phase circuit is 76.4 in case the company erects its own power house and 57.4 miles in case power is purchased from the Commonwealth Edison Co., delivered at [illegible] sub station. Two oil switches are placed on each line. It may be as desirable to install but one on the power house end of each line.

Steel poles are assumed for all lines.

Distance between poles on tangent is 150 feet. Fig. 61 shows structural details of the high voltage pole line north of Burnside.

The average loss of voltage from power station at Windsor Park to substations during rush hours is on the basis of .9 power factor of load, to [illegible] 110 volts, to [illegible] 233 volts, to 12th St. 314 volts, to Burnside 73 volts, to [illegible] 138 volts, to [illegible] 172 volts. This assumes all conductors in parallel with south lines feeding from cut off via South Chicago. The voltage regulation is 1.7 % average at 12th St. sub station and less than this at other sub stations during rush hour. This may become 5 % for a peak fluctuation during rush hour at 12th St.

[illegible]

The Sprague Wilgus type of third rail is proposed for this system. This is an undercontact protected third rail providing minimum equipment interference and is in use in the electric zone of the New York Central, the West Shore Ry. between Utica and Syracuse, New York Auburn and Lansing R. R. and Philadelphia Rapid Transit elevated and subway lines. The most important question is that of maximum clearance. The limitation on third rail position for this road occurs at the overhead crossings where bridge gussets permit a maximum distance of 53 in. from the center of third rail to track gauge line. This is 4 3/4 in. greater than the similar dimension for the New York Central Electric zone and 1 in. greater than in the case of the West Shore R. R. The location is in fact the greatest distance from track rail in use by any railroad and will, so far as the writer is aware, permit the passage of all types of cars

likely to be offered the company for haulage.

It is particularly fortunate that such an advantageous location for the third rail can be found, since the main line tracks from Kensington to Flossmoor are to be equipped, and any location not permitting the passage of low hopper coal cars would be prohibitive. The third rail weighs 80 lbs. per yard and is of special composition having a resistance about 7.5 times that of the equivalent cross section of copper. Its resistance including bonds will be about .041 ohms per mile. Bonds are 2-400 000 C.M. soldered per joint, 18 inches over all length when soldered. Details of third rail structure at overhead crossings is shown in Fig. 44. This also shows the type of fibre protection to be used. 64.8 miles of third rail structure are to be provided and 200 complete crossing jumper installations.

The third rail switching and control system has been designed to provide extreme reliability of operation on the portion of the system north of Kensington. South of this point where the frequency of service is less, a cheaper method of switching is used which nevertheless provides for nearly the same flexibility of operation. Fig. 45 shows this method of switching. North of 67th St., the method is the same as used in the electric zone of the New York Central R. R. This provides for cross connecting the third rail at two points between sub stations by means of interconnecting circuit breakers that trip automatically, but are capable of being operated from adjacent sub stations. In addition there are

provided enabling 300 Volt feeders which make possible continuous feeding to any section or provide a means to bridge over a completely disabled section. Normally all third rails are inter-connected at sub stations and at circuit breaker houses in order that complete advantage may be taken of the conductivity of all third rails to any point.

At each sub station, there is provided an isolated third rail section 500 ft. long. This is to prevent a train bridging across from one section to the one adjacent in case of trouble on either one, and thus making alive one section when it should be dead.

South of 67th St., as far as the terminal, the third rails are tied together simply between sub stations through fuses and knife switches. In case of trouble on any section, the circuit breaker at the sub station and the fuse at the section switch are automatically opened. When the trouble is removed, the sub-station circuit breaker is closed, and the section is ready for temporary operation, the fuse being replaced at leisure. There is no provision for emergency feeding, the sectionalization is less complete, and there is not so quick return to normal conditions after trouble, as is the case with the system north of 67th St. This system of sectionalizing third rail was introduced by the West Jersey and Sea Shore R.R., Camden-Atlantic City line.

The method of connection of the circuit breakers in the circuit breaker houses as used for the lines north of 67th St. is shown by Fig. 44.

RETURN CIRCUIT

Owing to heavy current to be carried, it is necessary to use both running rails for track return. The signaling must be done in a manner that will permit this. It is best accomplished by providing alternating current for signal purposes; and sectionalizing the track as regards this current by means of reactance bonds that permit passage of direct current for traction but are high reactance choke coils to the alternating signal circuit.

Figs. 2, 3 and 4 show the weight of track rail on various portions of the line. The Blue Island and South Chicago branches are in poor condition as regards rails, and it is recommended that 75 lb. rails be relaid on these lines at the time of installing electric apparatus. There should be at least 500 000 C.M. bond section at each track rail joint. About 50 000 joints must be equipped in this manner.

The extent of cross bonding is dependent upon the signal system layout. On local tracks from Randolph St. to Kensington, crossbonding can occur at signal positions, about 1500 to 2500 ft. apart. It is desirable to cross bond express tracks at those points as well if the signal system will permit; and to tie the four tracks together every 2500 ft. by means of a 750 000 cm. wire cable laid transversely with the tracks. South of Kensington where block signals are not used, cross bonds of aggregate 750 000 cm. should be placed at intervals of 2000 ft.

SIGNAL SYSTEM.

The signal system in use at present provides for straight block signalling (no overlaps) for all suburban lines from Randolph St. to Kensington. About 80 Hall Banjo signals are necessary for the suburban system at present. Fig. 9 shows the present location of signals controlling suburban tracks. On the lines from 67th St. to Kensington [illegible] signals should be provided controlling blocks between stations, that is, all times that the train should be operated at full speed. [illegible] signals for each track are required for this use. In all, there are required 110 signals to give required signal protection of electrically equipped lines.

Signal systems of the kind necessary for this service are costly and require numerous special devices for their operation. The signal system from Grand Crossing to Kensington could perhaps be dispensed with since traffic on this portion is very light. In this event only 87 signals would be required for the equipment of the installation. Signal systems which fulfill the general specifications noted herein can be supplied by the General Railway Signal Co., the Union Switch and Signal Co. and others.

The writer has been unable to obtain satisfactory price data on these systems, and hence the cost of new signals is not included in the cost estimate for the proposed electric system. It is possible that it would be cheaper to install a single small auxiliary continuous third rail to operate the present Hall signals than to invest in a costly outfit for alternating current signalling.

CARS.

For electric service operating according to the provisional schedule of Figs. 29 to 40, 112 cars of multiple side door type are needed. Details and dimensions of these cars are shown on page 20 and weights in Table IX. Certain slight construction changes must be made in order to adapt the present side door car for electric service. The Pintsch gas apparatus must be removed and lights and heaters installed. A knockdown motorman's cab is to be placed at each end of car. It is recommended that the brake rigging be changed to Westinghouse Quick Acting Air Brakes with graduated release Schedule A.M.L. on all present cars as well as new equipment.

In order to adapt a present side door car for operation as a motor car, the most extensive structural change necessary is to reconstruct the body bolster at one end in order to accomodate motor truck with its two motors. Fig. 65 shows a tentative design for this work. In the new cars to be built, some other method of underframing must be worked out that will more easily adapt itself to use of motor trucks.

The car lighting is to be arranged in clusters similar to present Pintsch gas lights. In addition, there is to be provided a row of lights along the side of car above the door sills. Thirty 32 C.P. lamps with holophane globes suffice for the clusters, and twenty 16 C.P. lamps with frosted bulbs for side lighting. Electric heaters are to be installed transversely under the cross seats. 24 units similar to type 115 W supplied by the Consolidated Car Heating Company are necessary. Each car is to be furnished with two illuminated destination signs [illegible]

frame is used by the Metropolitan Elevated R. R., Chicago. A sand funnel, from sheet, is to be mounted on the outer end of each truck [illegible] to direct sand to flange; [illegible] not more than [illegible] degrees horizontal. Support for an electric arc headlight is to be furnished at each end of car in center of [illegible] one foot below roof line. Fig. 71 shows the appearance of a fully equipped motor car.

The pressed trucks may be used as trailer trucks. For motor trucks a design following the lines of the specified trailer truck can be built, but such a type is [illegible] used for heavy motor trucks in the United States. This is commonly called the M.C.B. type. The [illegible] and [illegible] use this type of truck [illegible], and the [illegible] uses it for the type [illegible], 113 motor (200 H.P.). The New York Central uses a cast steel solid frame truck [illegible] elliptic springs. Similar trucks are used [illegible] for suspension of the [illegible] motor and other heavy motors.

The particular type to adopt is largely a matter of personal preference. For very high speeds and relatively low tractive effort [illegible], the [illegible] is to be recommended. For lower speeds and heavy pulls such as [illegible] when a low speed gear ratio is adopted, the solid frame truck is preferable. There is no doubt that at speeds approaching 60 M.P.H. the M.C.B. type is the easier riding truck; also that at heavy pulls and braking forces, the M.C.B. type is subject to very severe racking stresses, which are not so noticeable with the solid frame truck due to the greater distance between spring suspension points.

As a general recommendation it is advisable to use the solid frame truck for slow speed short run service. Thus for the G E 69 motors for the London Underground Elec. Co. equipments, the solid frame was chosen, since the maximum pull per truck is 11000 lb. during acceleration; whereas for the West Jersey and Sea Shore R. R., the M.C.B. design is justified since the maximum speed is above 60 M.P.H. and the maximum pull per truck is but 6000 lb. during acceleration.

In the case of the I. C. R. R. suburban cars it seems advisable to adhere to the M.C.B. design built according to the following specifications: -

Wheel base	90 in.
Wheel diam.	36 in.
Height center plate above rail	32 in.
Height side bearing above rail	[illegible] in.
Cen. to Cen. of side bearings	61 1/2 in.
Weight of motor on transom	3500 lb.
[illegible]	[illegible] lb.
Probable weight of truck	15000 lb.

POWER HOUSE - 600 VOLT. SYSTEM.

It is not the intention to discuss in detail the design of a power house. There is a strong probability that the Commonwealth Edison Co. will supply power at a rate such that the advisability of a power plant would be questionable. This is especially true for the first five years of electric operation during which time it is assumed the traffic will be developing from the present amount up to the amount as per the provisional Schedule of Trains, [illegible] to [illegible]. The rate at which the Commonwealth Edison Co. would supply power would probably be

1/2 c per Kilowatt hr. plus
$15.00 per year per K. W. of 5 minute maximum demand.

This brings the cost very close to 1 cent per K.W. hr. for a load factor of .33 (See Fig. 60)

[illegible] to build a power plant. Its [illegible] to operate trains according to the provisional schedule.

Generators,
3-5000 K.W. Turbo generators, 25 cycles, 2300 volts, Delta connected. Overload capacity 50 % for 3 hours.

This permits [illegible] load during a rush hour with one unit in reserve.

Boilers,
12 - Water tube type with mechanical [illegible] sq. ft. surface each and 100 - 125 [illegible] each. Nominal rating 525 h.p. each. [illegible] degrees superheat.

Stacks,
3 - Self-supporting steel 250 [illegible]

Location of Plant [illegible]. This location is the nearest practicable point to the electrical center of gravity of load of the entire system which is very close to [illegible]

COST OF EQUIPMENT 600 VOLT SYSTEM.

In the following, are cost estimates for the equipment of the entire suburban zone with the direct current third rail system operating at 600 volts, - 2 G E 69 B motors per car; based on Provisional Schedule that provides for 76 % increase in number of trains, 50 % increase in car mileage, and 154 % increase in seat mileage above present steam schedule. Cost of signal system and relaying track on South Chicago and Blue Island branches is not included. Power assumed purchased from Commonwealth Edison Co.

Transmission Line: -	
57.4 miles 3 phase line 2/0 cable 17.6 miles 2 circuit line. 7.4 miles 3 circuit line. Steel towers 150 ft. apart. Switching to busses included.	$ 240 000
Sub-stations: -	
7 buildings with 23 - 1000 K.W. convertors, transformers	848 000
Third Rail: -	
84.5 miles 80 lb. special protected type	520 000
Feeders and Circuit Breaker Houses;	69 000
11 miles 1 000 000 C.M. 5 circ. breaker houses and control.	
Bonding:-	
84.5 miles single track	85 000
Cars:-	
Equipping 17 side door cars with motor equipment trucks and compressors $119 000	1,271 300
95 new side door cars complete $1 125 300	
2 work cars 4 motors each $27 000	

Passenger Station lighting motor generators at 26th St. Outlying stations from third rail	$ 9 000
Inspection and Repair shop extra equipment	50 000
Total (not incl. signals or power house)	$ 3 090 300
With power plant add extra for Transmission line	51 000
Power plant extra (about)	1 400 000
Total incl. power plant.	$ 4 541 300

[illegible]

The use of forced ventilation for railway motors occurs with the equipments of the Detroit River Tunnel Company, the New York New Haven and Hartford R. R., the Sarnia Tunnel locomotives, the Metropolitan Ry. Co. London, Eng. locomotives, the motor cars of the Midland Ry. Morecombe-Lancaster-Heysham branch and others.

The recent development of the interpole railway motor has made it possible to design direct current railway motors such that the full benefit of forced ventilation is attainable. It is entirely practicable to double the output of a motor both for continuous and peak outputs by the use of forced ventilation provided interpoles be used which eliminates sparking as an output limitation. Once there is a general appreciation of this fact, the author predicts a very extensive use of forced ventilation for all classes of railway service.

In the case of [illegible] motor cars, it would be possible to substitute for the [illegible] motors, an equipment of two 200 [illegible] or 115 [illegible] interpole motors with forced ventilation, [illegible] to operate [illegible] to the characteristics of the [illegible] motor and [illegible] H.P. each during acceleration. This introduces a great saving [illegible] cost of equipment and a considerable saving in cost of power [illegible] the reduction of train weight by 5 tons. The extra output for the ventilating motor would be about 1.5 K.W. per car.

A still more economical method of realizing from the capabilities of forced ventilated motors is to use a larger G.E., say nominal 150 or 200 H.P. frame size, and operate it at double rating; but use trains made up partially of motor cars and partially of trailers. If this method be adopted, the present side door cars can be used for trailers with but a slight cost to re-equip them with train lines, lights, heaters etc. The control apparatus must be more liberally designed since currents up to 700 amperes per motor must be handled during acceleration. The weight of blower motor outfit will be 400 lbs. and its cost about $200.

Two 150 H.P. frame size interpole motors, wound to operate with forced ventilation, and thus become nominal 300 H.P. motors, will cost about the same as a double equipment of G E 69 B motors. However only two thirds as many equipments are necessary; that is, of the 110 total cars, but 75 need be motor cars. This seems to be the best equipment for the service, since considerable difficulty will be found in providing space for ventilating ducts with the 200 H.P. frame size interpole motor.

In addition, the 300 H.P. output during acceleration per motor axle is about all the wheels will stand without slipping unless sand be provided. At this output the percentage of adhesion is 10 % of weight on motor axle.

Trains of various lengths would then be made up as follows:-

	No. of motor cars	No. of Trail cars
1 car train	1	0
2 car train	2	0
3 car train	2	1
4 car train	2	2
5 car train	3	2

Since the majority of trains during rush hours are 3 car trains and during non-rush hours are 2 car trains, it will be seen that the ratio of motor cars per train (.66 - .60) is one corresponding to the increase of power obtainable from the motors as compared with that obtainable from the G E 69 B motors.

Fig. 66 shows characteristic curves of a motor with interpoles to operate at 200 H.P. rating, when provided with forced ventilation. The total weight of a three car train loaded is 165.0 tons; which is to be compared with a train weight of 176 tons with the G E 69 B equipment.

Fig. 67 shows a typical run curve for this system. The energy input averages 119 K.W. per car including blower motors. This is a saving of 5 % as compared with the G E 69 motor equipment.

The largest monetary saving occurs in the item of cars which [illegible] be compared with the estimate page ~~67~~ 71 to be.

Cars;		$1 053 000
Equipping 17 side door cars as trailers	$ 12 000	
20 new trail cars	$132 000	
72 motor cars	$882 000	
2 Work cars (4 motors)	$27 000	

Or a saving of $164 000 in first cost of equipment. The annual saving of energy cost due to the use of these motors is $16 500 with purchased power at a rate noted elsewhere (page ~~66~~ 70). In addition there is a considerable saving of maintenance of motor equipment due to the use of fewer motor cars.

The other details of the electric equipment as developed by a study of the [illegible] motor such as provisional schedule, sub-station, and 3rd rail equipments, are identical for this system using forced ventilation for cooling motors.

Although the use of forced ventilation for direct current motors has not been given the extended use that its advantages warrant, chiefly due to the very recent development of the interpole motor, there is no doubt whatever but that it is the system to use in case the 600 volt third rail system is adopted for the [illegible] suburban service.

DIRECT CURRENT 1200 VOLT SYSTEM
FORCED VENTILATED MOTORS.

Certain engineers have been persistent advocates of a system employing 1200 to 1500 volts at the car. The use of an interpole motor operated two in series at 600 volts is necessary, or else a motor operating directly on 1200 volts must be provided. In the former case, it is necessary to insulate the motors for 1200 volts; since one of the pair is at this potential relative to ground. This causes about 25 % reduction in output as compared with a standard 600 volt motor of same frame size. A considerable extra rheostat loss is occasioned by this method, due to the impossibility of using a series parallel combination in starting with two motor equipment. For the case of the I. C. R. R., this would mean 15 % increase of energy required as compared with the straight series- parallel control or a 20 % increase as compared with the modified series - parallel method proposed for this service. (See page ~~43~~ 44 and appendix C)

A 1200 volt direct current motor of the large size required for this work is entirely practicable, and such a motor need be no more bulky than a 600 volt motor of same rating. This is for the reason that the decrease in output due to necessity for heavier insulation can be largely counter balanced by increased armature core length; since the commutator can be considerably shortened, due to the lesser current commutated.

The third rail method of collecting current can be adopted for this system. The 65 lb. third rail proposed for this system is

illustrated in Fig. 68. A similar third rail for 1200 volts has been designed for the California Midland R. R.

The motors can be designed to possess characteristics identical with those of the motor for 600 volts forced draft. They will probably weigh 500 lb. more each, and will cost 25 % more than the G E 69 B motor equipment.

For this system, a distribution system employing sub-stations is shown in Fig. 69. The system shown will provide equal reliability and percentage of conductor loss as does the layout proposed for the 600 volt system. See Fig. 45. The rotary convertors would be 1500 K.W. units as follows:

[illegible] St.	3 - 1500 K.W.	convertors
Grand Crossing	3 - 1500 K.W.	"
147th St.	3 - 1500 K.W.	"
Total	13500 K.W.	"

Since these convertors must be wound for 1200 volts, it is estimated that they will cost 10 % higher per K.W. than do the 1000 K.W. 600 volt units.

ESTIMATED COST OF [illegible] 1200 VOLT
[illegible]
[illegible] SUB-STATIONS.

The following is a cost estimate for the 1200 volt forced ventilated motor system using third rail, and that operates trains according to the Provisional Schedule of Figs. 29 to 40.

Transmission Line		$ 190 000
Sub stations		690 000
Third Rail		598 000
Feeders and circuit control		84 000
Bonding		65 000
Cars,		1 154 000
Equipping 17 side door cars as trailers	$12000	
20 new trail cars	$132000	
75 Motor cars new complete	$980000	
[illegible]	[illegible].	
Passenger station lighting		9 000
[illegible]		[illegible]
Total (not incl. signals or power house)		$ 2 860 000
With power plant add extra for Transmission line		31 000
Power plant (about)		1 400 000
Total incl. power plant		$ 4 291 000

The use of the high operating potential of 1200 volts makes possible an economical system of distribution of power from direct current power stations. In case the railroad company decides to erect its own power plant, this possibility should be carefully considered. 600 volt turbo generators are in use up to 2000 K.W. size in Europe and the writer believes that 1200 volt direct current turbo generators could be furnished by American manufacturers in capacities up to 3000K.W. The standard method of construction could be used or a homo polar generator adopted. There is already operating a 2000 K.W. homopolar generator for 300 volts and the possibility of this type should be considered.

It is possible to erect two of these direct current generating stations, one at 43rd St. on the Lake Front with eight 2000 K.W. units and the other at Riverdale with 2-2000 K.W. units. The third rail system must be reinforced with feeders to give equal conductivity as compared with the system employing three sub stations. This layout is shown in Fig. 70.

The reliability of operation of this system is not equal to that employing 20,000 volt high voltage lines which could be supplied from the Commonwealth Edison Co. in case of emergency. The works cost of power also would be about .7c per K.W.H. as compared with .6c per K.W hr. for a single power plant feeding a 20,000 volt transmission system. On the other hand, the energy output per annum for this system is decreased 10 % due to elimination of rotary convertor sub-stations.

A further advantage of this system employing two direct current power houses is that the 43rd St. power house can be built first, and the entire north end of the system to Grand Crossing and South Chicago can be placed in operation, before work on the south end is begun.

[illegible] DIRECT CURRENT
[illegible]

Following is an estimate of cost for this system to operate trains according to the Provisional Schedule of Figs. 32 to 43.

Third Rail	$ 592 000
Feeders and circuit control system	300 000
Cars	1 124 000
Bonding	65 000

Passenger Station lighting	$ 9 000
Inspection and repair shop equipment	50 000
Total not incl. signals or power house	$ 2 [illegible]
Two Power plants (about)	1 [illegible] 000
Total incl. power plant	$ 4 376 [illegible]

[illegible] SYSTEM.

This system requires the use of overhead conductors, operated at 6600 volts potential without the intervention of sub stations. This potential is the standard for the Commonwealth Edison Company on the [illegible] portion of the high voltage network. It seems advisable to [illegible] the construction of the lines for 22,000 volts, — the highest standard voltage of the Commonwealth Edison Company. The system with 6600 volts trolley potential is used by the Kensington and Eastern R. R. and the Chicago Lake Shore and South Bend R. R., the cars of which enter Chicago over the I. C. R. R. tracks from Kensington. If the single phase system be adopted for use by the I. C. R. R., these trains can enter Chicago under their own power.

It is difficult to provide a method of overhead construction that can be easily extended, in case the main line tracks within the suburban zone be equipped for electric operation. Such a provision was predicated early in this study. There will also arise difficulty in obtaining permission to erect a structure over the tracks from 12th St. north on account of the outer parkway agreement with the City of

Chicago. There is also liable to be considerable opposition to the erection of an overhead line for the tracks on the Lake Front from 53rd St. north. No matter how substantial be the construction, the overhead work is bound to be unsightly.

As a solution of the overhead construction problem, the writer would recommend the use of a light steel bridge span for double tracks, two such structures to be installed from 67th St. to Van Buren St., one over the local tracks and the other over the through tracks. The arrangement is such that in the event of extending the overhead system to the main line tracks, it can be done by adding another bent of bridge work between these then existing; and using the inside posts of the outer bridge work to support the middle bent. These inside posts are made heavier with this in view. Fig. 72 shows this overhead bridge construction on the Lake Front portion. The probability is very remote of extending the main line electrification further south than Fordham Yard, the end of the track elevation. For this reason no provision has been assumed for main line track overhead structure south of Woodruff. (Except in the estimate for the entire suburban service from Kensington to Flossmoor.)

Double catenary construction, 0000 steel trolley conductor suspended and auxiliary 0000 copper wire from 5 - 16 in. messenger wires, 300 ft. span, will be ample for this section; and with a single power station at [illegible] will give lower percentage of voltage drop than is assumed for the direct current systems. Fig. 75 shows the method of sectionalizing the overhead trolley for this system.

The type of overhead construction is high enough to avoid [illegible] to passenger or freight trains. Undercrossings occur only near [illegible] St. and here the suburban and freight tracks do not interfere. Considerable special work must be done at these crossings and for the local tracks at 12th St. yards but the difficulties are comparatively slight. Altogether a thoroughly satisfactory scheme of overhead construction can be developed.

MOTOR EQUIPMENT.

Provided forced ventilation is not resorted to, an equipment of 4 - 125 H.P. motors per car is necessary. These may be of the [illegible] type ([illegible]) or of [illegible] type (Wgh. 148). In either case the cost of this equipment is very high. Thus, with 4 - G E [illegible] motors as used by Richmond and Chesapeake Bay R. R., Washington Baltimore and Anapolis Ry. and others, the weight of a motor car loaded with 150 passengers is 70.2 tons and the weight of a three car train 210.6 tons as compared with 152 tons as the weight of a three car train using forced direct current ventilated motors, or 175 tons with G E 69 B motors with natural ventilation. The energy required at car is nearly in proportion to these weights; since the modified method of direct current control (appendix B) is nearly as efficient as the auto transformer method when there is considered the lower operating efficiency of the alternating current motors.

[illegible] - [illegible] - [illegible]
SYSTEM 4 - G E 603 OR W.H. 148 MOTORS
PER CAR

Following is an estimate of cost for equipping the entire suburban system to operate according to the provisional schedule.

Trolley and bridge construction 37.8 miles of double track double catenary Steel bridges. 5 miles single track steel poles		$ 588 500
Sectionalizing apparatus		11 400
Transmission Line 2 - 4/0 cables 37.8 miles		69 000
Cars,		
Equipping 17 side door cars as motor cars	$268 000	
		2 035 000
96 new motor cars	1 767 000	
2 Work cars	$30 000	
Bonding,		75 000
Passenger Station lighting		11 000
Inspection and repair shop equipment		50 000
Switch House at Woodlawn (for Edison connection)		40 000
Total (not incl. signals or power plant)		$ 2 879 900
Power Plant (about)		1 400 000
Total		$ 4 279 900

The total power output per annum with this system is 34 % greater at the car or ~~[illegible]~~ 22% greater at the power house than the output with the G E 69 B motors on cars (See Fig 89). The maintenance of electric equipment will be more than doubled due to the use of four motors per car each of alternating current type.

ALTERNATING CURRENT SYSTEM WITH FORCED VENTILATED MOTORS.

This method is used by the Midland Ry. for their Morecambe-Heysham-Lancaster branch. It employs two motor equipments of the largest size available for use in the truck space. The Westinghouse No. 153 motor is used for a portion of this service and this motor is taken as a basis for this study. It is rated at 150 H.P.; but for the present study is assumed worked up to 180 H.P. net, at the end of acceleration period. The motor weighs 6000 lbs. complete, and the electrical equipment for a motor car weighs 22,400 lbs. including ventilating set. The weight of a three car train with these motors is 164.1 tons. Characteristic curves and speed tractive effort curve of this motor is shown Figs. 75 and 76. Parshall and Hobart page 478 "Electric Railway Engineering" publish a very complete description of this machine.

Fig. 77 shows the typical run using these motors. The time for run is 2 seconds slower than that necessary to equal the time with 4 G E 69 B motors. Inspection of Fig. 97 Appendix B shows that this performance with type #153 motor can be duplicated by an equipment of two direct current 175 H.P. motors (G E 68) per car. For runs in the Woodlawn local service the schedule speed would be 7 % slower than for an equipment using G E 69 B motors. For long runs above two miles the equipment furnishes slightly higher schedule speeds than does the G E 69 B equipment.

It is possible that by a method of operation whereby the motor voltage is raised 75 % above normal, so that initial rate of acceleration is continued, that the equipment will provide equal service as compared with the G E 69 B motor. Fig. 70 illustrates this method. The possibility of this temporary increase in motor voltage is a point to be decided by motor manufacturers. It is very doubtful to the writer whether such a method would be permissable in regular service.

It is very necessary that some such method be devised, or else that new designs be called for. This is for the reason that the provisional schedule is laid out for a minimum practicable layover; and the adoption of the W.H. 310 equipment without a positive guarantee that it would equal the service performance of the G E 69 B motors would necessitate a complete change in provisional schedule, with many more cars required to give same frequency of service.

In case the alternating current system be adopted it would be well to call for a new design that would have equal service performance as compared with the G E 69 B motor. It is very possible that the improvement in single phase motor design will permit a motor to be built weighing not over 6000 lbs, and which with forced ventilation, will give equal output as compared with the G E 69 B motor with natural ventilation,— plus that output required to move the excess weight of auxiliary electrical apparatus.

Assuming that this difficulty can be successfully overcome, the single phase forced ventilated motor system is directly comparable with the other systems previously considered. The following cost estimate for trains operating according to the provisional schedule is made up on this basis:-

ESTIMATE OF COST SINGLE PHASE ALTERNATING CURRENT SYSTEM WITH WGH. NO. 133 MOTORS FORCED VENTILATED

Trolley and Bridge construction		$ 588 500
Sectionalizing apparatus		11 400
Transmission line		69 000
Cars		
Equipping 17 trail cars as motor cars	162,000	1 702 000
93 new side door cars equipped	1,500,000	
2 work cars 4 motors each	40,000	
Bonding		75 000
Passenger station lighting		11 000
Inspection and repair shop equipment		50 000
Switch House at Woodlawn (Edison connection)		40 000
Total (not incl. signals or power house)		$ 2 596 900
Power House (about)		1 400 000
		$ 3 996 900

The energy required for this system is 3 % greater at cars than that required for the system using G E 69 B motors and 8 % less at power station.

COMPARISON OF SYSTEM

In the following tables showing the comparative items for the various electric systems, a conventional designation for the systems is adopted as follows: -

System 1.
600 volt direct current Third Rail - 2 G E 69 B motors per car. All cars motor cars. No forced ventilation of motors. 7 sub stations fed from 20,000 volt line.

System 2.
600 volt Direct Current Third Rail - 2 (G E 207) motors per car wound to operate with forced ventilation. 66 per cent of all cars are motor cars. 7 sub stations fed from 20,000 volt line.

System 3.
1200 volt Direct current Third Rail - 2 - 1200 volt interpole motors per car wound to operate with forced ventilation. 66 per cent of all cars are motor cars. 5 sub stations fed from 20,000 volt line.

System 4.
1200 volt Direct current Third Rail - 2 - 1200 volt interpole motors per car wound to operate with forced ventilation 66 per cent of all cars are motor cars. Two direct current power stations generating at 1200 volts.

System 5.
Alternating current single phase 25 cycles 9000 volts on line. Overhead double catenary supported by steel bridges spanning double track. 4 - Wgh. No. 144 motors per car. Not forced ventilation. All cars motor cars. Single power station.

System 6.
Alternating current single phase 25 cycles 9000 volts on line. Overhead double catenary supported by steel bridges spanning double track - 2 Wgh. No. 135 motors per car with forced ventilation. All cars motor cars. Single power station.

In Table XVI there is a comparison of first cost of system to operate the entire suburban service with trains operating according to provisional schedule. This provides for 72 % increase in number of trains, 53 % increase of car mileage and 154 % increase in [illegible] mileage

over and above that furnished by present steam schedule. These costs do not include new signal system. (See page 66)

TABLE XVI.
COMPARISON OF FIRST COST.

	Company Builds and operates own Power House	Company Purchases Power from Com. Edison Co.
System 1	$ 4 676 300	$ 3 211 300
System 2	4 512 300	3 047 300
System 3	4 380 000	2 940 000
System 4	3 376 000	
System 5	4 279 900	2 879 900
System 6	3 996 900	2 596 900

In comparing costs of power the following are the assumed conditions. If purchased from Commonwealth Edison Co. .5c per K.W. hr. plus $15.00 per year per Kilowatt of 5 minute maximum demand. If generated in company's power house at 20,000 volts alternating current, 0.6c per K.W. hr. and 0.7c per K.W. hr. if generated at 1200 volts in two direct current power houses. In the last two cases, interest on invested capital in power plant is 5 %, taxes 1 %, depreciation 5 %. Total fixed charges at power plant 11 %. The values of energy required are obtained by reducing the amount "for traction only" of Fig. 60 in proportion to the calculated energy required for a typical run of a three car train with various systems. The other items of output are then added as the conditions may be. It should be noted that this estimate of power cost includes power for lighting cars and stations, and for car heating.

TABLE XVII.

COST OF POWER AND ENERGY - PROVISIONAL SCHEDULE

	Total K.W. Hrs. Output	Maximum demand	Company Operates own power house	Company Purchases power.
System 1	46 485 000	15 400	$ [illegible]	$[illegible]
System 2	45 075 000	14 900	[illegible]	[illegible]
System 3	45 075 000	14 900	[illegible]	[illegible]
System 4	[illegible]	[illegible]	[illegible]	
System 5	53 800 000	17 800	476 500	536 000
System 6	44 920 000	14 900	425 000	[illegible]

An approximate estimate of the amount of the account "Maintenance of Electric Equipment" per annum is shown in Table XVIII. Special attention is called to these low values, since the car mileage per year approximates [illegible]. Experience for many years in heavy direct current roads has shown these values to be conservative, and a sufficient margin has been added for the alternating current equipments on account of their greater complexity.

TABLE XVIII.

MAINTENANCE OF ELECTRIC EQUIPMENT - CARS PROVISIONAL SCHEDULE.

System 1	$ [illegible]
System 2	[illegible]
System 3	[illegible]
System 4	[illegible]

System 5	$ 186 000
System 6	102 000

MAINTENANCE OF ELECTRIC SUBSTATIONS.

System 1	3 000
System 2	3 000
System 3	2 500
System 4	
System 5	
System 6	

The maintenance of electric circuits should not exceed $15,000 per year with the overhead system or $9,000 per year with the third rail system.

Cost of operation of sub stations will be as follows:-

System 1	$ 56 000
System 2	56 000
System 3	37 000

In the following Table XIX will be found the sum of the folowing items;

(1) 11 % for interest, depreciation, and taxes on all equipment exclusive of power house.

(2) Power charge per annum from Table XVIII with company operating power house, includes fixed charges on power house.

(3) Maintenance of Electric Equipment cars. — Table XVIII.

(4) Maintenance of Electric Equipment sub staions — Table XVIII.

(5) Maintenance of Electric [illegible].

(6) Operation of sub stations.

While these figures mean little in themselves, the difference between them can well be taken as the difference in cost per annum of the various electric systems.

System 1	$ 925 200
System 2	860 500
System 3	869 000
System 4	775 000
System 5	993 500
System 6	825 500

From these cost estimates, the writer has no hesitation in recommending for adoption System 4; that is, two direct current power stations generating current at 1200 volts and distributing by means of 3rd rail reinforced by copper feeders. It is the writer's opinion that an even better showing could be made by this system in the item "power house", which are here assumed 25 per cent more costly than the alternating current power plants. The small size of units ([illegible]) at the power house permits the use of a power plant built on the double deck principle similar to Hamilton and Spy Run plants.

From an engineering standpoint this system of traction is very attractive, providing as it does such a marked decrease in cost as compared with the standard 600 volt system; and at the same time furnishing nearly equal reliability and service. As a system, the machinery is not yet on such a sound commercial basis as is the case with some of the other systems; and hence some difficulty may be had in obtaining satisfactory deliveries on the apparatus. Owing to this, the estimated time for installation of the system is two years, as opposed to about ten months for the standard direct current 600 volt system.

OPERATING EXPENSES.

The writer has not had access to the detailed accounts for the present steam suburban system, and is therefore unable to estimate total operating expenses for the system of electric operation. It is believed that sufficient data is given in this report to enable one conversant with present operating costs to quickly estimate the same for electric operation. In doing so it must be remembered that the item "cost of power", of Table XVII, includes all operating and fixed charges of power plant and is an item that would be paid per annum say to a subsidiary company owning and operating the power plant. The unit cost 0.7 c per k.w. hr. really represents all power station operating expenses including cost of coal, maintenance of equipment, and salaries of employes. In comparing the items of the steam tabulation, "maintenance of steam-equipment - locomotives" must be directly compared with "maintenance of electric equipment - cars" for the new service. The charge "engine service" is properly to be compared with the item "cost

[illegible] It [illegible] be remembered that the figures given for electric service in Tables XVI et seq are for a considerable [illegible] [illegible] % increase in number of trains, [illegible] % increase in car miles, and 134 % increase in seat miles.

ESTIMATE FOR COST OF INITIAL INSTALLATION TO COVER ENTIRE SUBURBAN ZONE.

The cost of an initial installation providing about equal car miles per annum as at present; and covering the entire present suburban zone with trains operating according to provisional schedule, but with fewer cars per train is given below. All items are considered such that the extension of the service to the provisional schedule basis can be accomplished merely by purchasing more cars, [illegible] generating apparatus, and more feeder copper. This is with the idea that all rush hour trains shall be 3 car trains only and that the midday trains will average 2 cars instead of 3.

1200 VOLT SYSTEM TWO DIRECT CURRENT POWER STATIONS

Third Rail 84.5 miles		598 000
Feeders and [illegible] system		90 000
Cars, Total No. 74		
Equipping 17 side door cars as trailers	$12,000	757 000
7 new trail cars	45,000	
50 motor cars complete	672,000	
[illegible]	[illegible]	
Bonding		65 000

Passenger Station lighting	9 000
Inspection and shop equipment	30 000
Total (not incl. power plant or signals)	$ 1 549 000
Two Power plants (about)	1 100 000
Total	$ 2 649 000

ESTIMATE FOR COST OF EQUIPMENT OF WOODLAWN LOCAL SERVICE - CONT.

The cost of an installation for the Woodlawn Local tracks with a view to inaugurating a 5 cent fare is shown herewith. The trains operate according to the provisional schedule, for details of which see page 50 . This provides a two car train every 15 minutes during the day and a five car train every five minutes during the rush hours. With no greater outlay for first cost, the midday trains can as well be three cars instead of two.

Third rail (18 miles)		$ 126 000
Circuit control system (C.S. Houses)		45 000
Cars Total No. 47		
Equipping 15 side door cars as trailers	18 000	447 000
Equipping 1 side door cars as motor cars	15 000	
30 new motor cars	400 000	
1 work car (4 motors)	14 000	
Bonding		10 000
Shop equipment		28 000
Total not incl. signals or power plant		$656 000
Power plant (6000 K.W.)		660 000
		$ 1 316 000

Or, for this service, the Commonwealth Edison Company could furnish power from a substation at 43rd St. owned by the railway. This substation would not fit into the general scheme in case of extension but would perhaps be advisable for a temporary purpose. In order to be able to dispose of the apparatus when extensions are undertaken, the rotary convertors should be 600 volt machines operated two in series for 1200 volts,— each rotary frame to be insulated from ground. 3 sets of two 1000 K.W. rotaries would be required. In this case the cost would be

Total (not incl. signals or power plant)	$ 656 000
6000 K.W. substation	180 000
	$ 836 000

Either of these investments would furnish an exceedingly attractive service for the Woodlawn Local runs, and with the inducement of 5 cent fare along with a 16 per cent increase in speed, there should be no difficulty in making this service pay a handsome return.

ESTIMATE OF COST - WOODLAWN LOCAL SERVICE AND EXPRESS SERVICE TO SOUTH CHICAGO AND GRAND CROSSING. - THIRD TRACK SOUTH OF GRAND CROSSING.

This estimate is added with the idea that the advantages of electric traction would be very slight for the lines south of Grand Crossing and that passengers for these points (Kensington, Blue Island, and Flossmoor etc.) could as well change to steam operated suburban trains at Grand Crossing. The estimate is based on the provisional schedule all except the Blue Island and Flossmoor Express trains. In place of these there is assumed two extra Grand Crossing Express

trains that will take the place of the Blue Island and Flossmoor trains as far as Grand Crossing.

Third Rail (42 miles)		$ 298 000
Feeders and circuit control system		240 000
Cars. Total No. 90 Equipping 17 side door cars as trailers	$12,000	938 000
13 new side door cars	86,000	
60 new motor cars	810,000	
2 work cars (4 motors)	30,000	
Bonding		32 000
Shop equipment and inspection sheds		50 000
Total (not incl. signals or power plant)		$ 1 558 000
Power plant 12000 K. . (about)		1 320 000
		$ 2 878 000

If this project of leaving out of the electrification scheme, the portions south of Grand Crossing is decided upon; then below is an estimate for an initial installation by this method, providing for approximately same number of car miles as at present but still a 70 % increase of seat mileage on account of using side door cars.

[illegible]
TRACK SOUTH OF GRAND CROSSING.

Third rail,		$ 296 000
[illegible]		[illegible]
Cars, Equipping 17 side door cars as trailers	$ 12,000	600 100

Equipping 3 [illegible]	[illegible]	
40 new motor cars	540,000	
2 work cars	30,000	
Bonding		$ 32 000
Shop and inspection equipment		30 000
Total (not incl. signals or power plant)		$ 1 060 400
Power Plant 8800 K.W. (about)		880 000
Total		$ 1 940 400

[illegible]

The items of operating expense that are peculiar to electric traction and corresponding to these latter estimates are shown below:—

INITIAL INSTALLATION SEE PAGE ~~90~~ 94

Cost of power per annum including all fixed charges on power station	$ 305 000
Maintenance of electical equipment - cars	48 000
Maintenance of electric circuits	9 000

WOODLAWN LOCAL ONLY - SEE PAGE ~~91~~ 95

Cost of power per annum incl. all fixed charges on power station.	$ 194 000
Maintenance of electrical equipment, cars	18 000
Maintenance of electric circuits	4 000

WOODLAWN LOCAL AND [illegible]
[illegible]
SEE PAGE ~~92~~ 96

Cost of power per annum incl. all fixed charges on power station	$ 390,000
Maintenance of electrical equipment, cars	60,000
Maintenance of electric circuits	6.000

INITIAL INSTALLATION OF [illegible] - [illegible] 9397

Cost of power per annum incl. all fixed charges on power station	$ 295 000
Maintenance of electrical equipment cars	47 000
Maintenance of electric circuits	6 000

APPENDIX A.

The accompanying tabulation relates to the technical features of motor equipment as found on present operating railroads which employ the direct current 600 volt system of electric traction. These roads are chosen for comparison for the reason that they are in a way comparable to the I. C. R. R. suburban service as regards traffic and speeds. Certain English and European railroads are also tabulated for the reason that these are equipped with American built apparatus and as far as engineering features are concerned, they embody mostly American practice.

Compiled by
Tracy W. Simpson - 1908.

Third Rail System

	Loaded Train							
	Wheel Diameter Inches	Rate of Initial Acceleration M.P.H./sec	Speed to which initial rate is carried M.P.H.	Tons per Motor Light	Tons per Motor Loaded	H.P. per Ton Light	H.P. per Ton Loaded	Approx. Maximum Speed M.P.H.
Boston	33	1.51	15.7	15.0	17.3	11.7	10.1	40
Brookl	33	1.48	17.5	23.0	28.3	8.7	7.1	39
Manha	33	1.48	16.0	17.2	20.6	7.3	6.1	36
Interbo	33	1.29	18.0	26.8	34.0	7.5	5.9	39
	33	1.58	18.0	23.0	27.0	8.7	7.4	41
Hudson	33							
New Yo	36	0.79	24.3	35.5	38.8	5.6	5.1	48
Long I	36	0.92	26.0	29.4	31.7	6.8	6.1	46
West	36	1.02	29.2	22.5	24.9	8.9	8.0	60
	36	1.02	29.2	22.5	24.9	8.9	8.0	56
Market	33	1.55	16.0	17.5	20.0	7.2	6.2	37
Philade	36	1.32	22.0	8.8	9.8	8.6	7.7	46
Lackaw	36	1.34	24.0	16.8	19.0	8.9	7.9	46
West	36	1.12	26.0	8.8	9.8	8.6	7.7	53
South	33	0.91	19.0	17.1	19.9	5.2	4.5	35
	33	1.04	19.0	15.0	17.4	6.0	5.2	36
Northw	33	0.98	16.0	28.8	34.5	5.5	4.6	33
	33	0.98	16.0	28.8	34.5	5.5	4.6	33
Metrop	33	1.04	19.0	22.7	28.2	7.1	5.7	37
Aurora	36	0.71	32.0	18.0	20.2	6.9	6.2	58
Northw	33	0.73	27.0	21.0	24.0	5.9	5.2	50
Great	36			11.5	13.5	10.9	9.2	
Centr	35	0.84	18.0	31.0	32.8	4.0	3.8	30
Metro	38	1.53	19.0	23.0	27.5	8.7	7.3	45

APPENDIX A

TABULATION OF MOTOR EQUIPMENT

For heavy Urban and Suburban Railroads using the Direct Current 600 volt Third Rail System

Compiled by
Tracy W. Simpson – 1908.

Name of Company	Operating Division from which data is taken	Length Miles	No. of Stops	Length Avg. Run	Time for Total Run Minutes	M.P.H. Schedule Speed	Number of Cars per Train	Number of Motor Cars per Train	Number of Motors per Motor Car	Weight of Train Light Tons (2000 lbs)	Weight of Train Loaded Tons	Type Motor Used	H.P. each 1 hr. rating	Gear Ratio	Wheel Diameter Inches	Loaded Train		Tons per Motor Light	Tons per Motor Loaded	H.P. per Ton Light	H.P. per Ton Loaded	Approx. Maximum Speed M.P.H.
																Rate of Initial Acceleration M.P.H./sec.	Speed to which initial rate is carried M.P.H.					
Boston Elevated R. R.	Sullivan Sq. Dudley St. El. Line	5.18	10	52	22	14.3	5	5	2	150	173	GE 68C	175	3.28	33	1.51	15.7	15.0	17.3	11.7	10.1	40
Brooklyn Rapid Transit Co.	Williamsburg Broadway	6.25	16	39	24	15.8	6	4	2	184	226	Wgh. 300	200	3.37	33	1.48	17.5	23.0	28.3	8.7	7.1	39
Manhattan Elevated R. R.	3rd Ave. 200th St.	13.5	40	34	55	14.7	6	4	2	137	165	GE 66C	125	3.59	33	1.48	16.0	17.2	20.6	7.3	6.1	36
Interborough Rapid Transit Subway	Fulton – Lenox and 145th Exp.	9.8	10	98	36	16.3	8	5	2	268	340	GE 69B	200	3.15	33	1.29	18.0	26.8	34.0	7.5	5.9	39
do	City Hall 145th Local	18.8	27	36	45	13	5	3	2	138	162	GE 69B	200	3.15	33	1.58	18.0	23.0	27.0	8.7	7.4	41
Hudson and Manhattan R. R.	Hoboken – 19th St.	2.9	5	58	10	17.4	8	8	2			GE 76	160	3.26	33							
New York Central & Hud. Rv. R.R.	Grand Central – Mt. Vernon	13.1	13	1.01	38	20.7	6	4	2	284	310	GE 69C	200	1.89	36	0.79	21.3	35.5	38.8	5.6	5.1	48
Long Island R. R.	Flatbush Jamaica Local	9.6	6	1.60	23	25.1	5	3	2	176	190	Wgh 113	200	2.32	36	0.92	26.0	29.4	31.7	6.8	6.1	46
West Jersey and Seashore R.R.	Camden – Atlantic City Express	64.6	5	12.90	90	43.0	5	5	2	225	249	GE 69C	200	1.59	36	1.02	29.2	22.5	24.9	8.7	8.0	60
do	Camden – Glassboro Local	17.9	15	1.19	41	26.2	3	3	2	135	148	GE 69C	200	1.59	36	1.02	29.2	22.5	24.9	8.9	8.0	56
Market St. Elevated Passenger R.R.	South St. 69th & Market	7.4	18	.41	31	14.3	5	5	2	175	200	GE 66C	125	3.59	33	1.55	16.0	17.5	20.0	7.2	6.2	37
Philadelphia and Western R.R.	69th – Strafford	11.5	13	.89	28	24.6	2	2	4	70	79	GE 73	75	2.57	36	1.32	22.0	8.8	9.8	8.6	7.7	46
Lackawanna and Wyoming Valley Ry.	Scranton Wilkesbarre Local	18.3	14	1.30	40	29.0	2	2	2	67	76	Wgh 50	150	2.74	36	1.34	24.0	16.8	19.0	8.9	7.9	46
West Shore R.R.	Utica – Syracuse Local	48.6	21	2.31	117	25.0	2	2	4	70	79	GE 73	150	2.12	36	1.12	26.0	8.8	9.8	8.6	7.7	53
South Side Elevated R.R.	Congress – Loomis Express	8.8	15	.59	30	17.6	5	4	2	137	159	Wgh 121	90	3.41	33	0.91	19.0	17.1	19.9	5.2	4.5	35
do	Congress Jackson Pk. Local	8.6	21	.41	32	16.1	3	3	2	90	104	Wgh 121	90	3.41	33	1.04	19.0	15.0	17.4	6.0	5.2	36
Northwestern Elevated R.R.	Kinzie Evanston Express	13.2	21	.63	45	17.8	5	2	2	115	138	GE 55	160	3.29	33	0.98	16.0	28.8	34.5	5.5	4.6	33
do	Kinzie Ravenswood (Western Ave.) Local	7.7	23	.34	36	12.9	5	2	2	115	138	GE 55	160	3.29	33	0.98	16.0	28.8	34.5	5.5	4.6	33
Metropolitan West Side Elev. R.R.	Franklin – 52nd Ave.	6.5	18	.36	25	15.4	5	3	2	136	159	Wgh 114	160	3.28	33	1.04	19.0	22.7	28.2	7.1	5.7	37
Aurora Elgin and Chicago R.R.	52nd Ave. Elgin Local	35.0	16	2.21	64	32.8	2	1	4	72	81	GE 66B	125	1.66	36	0.71	32.0	18.0	20.2	6.9	6.2	58
Northwestern Pacific R.R.	Sauselito – San Rafael	13.0	11	1.18	32	24.5	3	2	2	84	96	GE 66A	125	2.07	33	0.73	27.0	21.0	24.0	5.9	5.2	50
Great Northern & City Ry.	Finsbury Pk. Moorgate St.	3.7	4	93			7	3	4	184	215	GE 66A	125		36			11.5	13.5	10.9	9.2	
Central London Ry.	Bank – Shepherds Bush	6.0	12	50	20	13.9	7	2	2	124	131	GE 66A	125	3.94	35	0.84	18.0	31.0	32.8	4.0	3.8	30
Metropolitan Ry.	Uxbridge – Aldgate	21.8	21	1.04	86	16.0	6	2	4	192	220	GE 69B	200	3.37	38	1.53	19.0	23.0	27.5	8.7	7.3	45
Metropolitan District Ry.	Hounslow – Barking	24.0	24	65	85	17.0	7	3	2	154	192	GE 69B	200	3.37	36	1.38	18.0	25.7	32.0	7.5	6.2	44
Great Western R.R.	Hammersmith Aldgate	8.5	14	.61			6	2	4	174	204	GE 76	160	3.50	36	1.52	15.0	21.8	25.5	7.3	6.3	32
Gr. Northern Piccadilly & Brompton	Finsbury Pk. – Hammersmith	9.4	20	.47	40	14.0	6	2	2	152	178	GE 69B	200	3.37	36	0.98	18.0	38.0	44.5	5.3	4.5	38
Baker St. and Waterloo	Paddington Eleph. & Castle	4.5	8	56	19	14.2	6	2	2	152	178	GE 69B	200	3.37	36	0.98	18.0	38.0	44.5	5.3	4.5	38
Charing Cross Euston & Hampstead	Golders Green – Charing X	6.5	11	.59	28	14.0	5	2	2	131	153	GE 69B	200	3.37	36	1.14	18.0	32.8	38.4	6.1	5.2	40
Lancashire & Yorkshire R.R.	Liverpool – Southport Local	18.5	15	1.23	37	30.0	4	2	4	144	162	Kerr 4A	150		42			18.0	20.2	8.4	7.4	
Northeastern R.R.	Central Tynemouth via Benton	19.6	13	1.50	51	23.0	3	2	2			GE 66	125		36							
Paris Orleans R.R.	Orsay – Juvisy Express	14.3	2	7.20	[illegible]	41.0	6	2	4	153	180	GE 66B	125	3.08	42	0.91	24.0	19.1	22.5	6.5	5.6	51
Paris Metropolitan R.R.	Section No. 3			.30		12.0	5	3	2		140	TH 10	175	2.44	34	1.20			23.4		7.5	
Rete Adriatica	Milan – Porto Ceresio	46.0	18	2.55			2	1	4	71	83	GE 55H	160	1.96	36	0.98	29.8	17.8	20.8	8.4	7.2	56

T.W.S.

CHAPTER X

STUDY OF CHOICE OF MOTOR FOR 600 VOLT DIRECT CURRENT SYSTEM.

By far the most useful data thus far published to aid in a preliminary determination of the relation of motor size to energy consumption and schedule speed, occurs in a paper by A. H. Armstrong. "High Speed Electric Railway Problem" Trans. A I E E June 1903. This data is in the form of a set of curves that show first, the horsepower rating of motor required for any train weight with motors geared to various maximum speeds; second, the schedule speed for any length of run when the maximum speed is thus determined; third, the energy consumption per ton mile at this schedule speed. These determinations are made for equipments having three train friction curves so that when the train friction curve of a proposed equipment is known, the schedule speed, energy consumption, and motor size are determined by interpolating according to the friction curve. These curves have been enlarged and others added by interpolation and are shown in Figs. 79 to 89 incl.

The writer has used this set of curves on many occasions where an approximate estimate is needed and has found the results so obtained to check closely with extended calculations based on the speed curve and thermal constants of a particular motor. The present instance has proven no exception to this statement but the importance of the case seemed to warrant a more extended study.

Applying the data from these curves to the case of the I. C. R. R. suburban service typical run of 0.815 miles we have the following Table XX, that shows the probable results for different sizes of direct current motors assuming all cars motor cars. Any combination of motors on motor cars and trailers will however give nearly the same results, provided the total horsepower of motors per train is as in the Table XX.

Table XX.

RELATION OF SIZE OF MOTOR TO [illegible] AND [illegible] SPEED, AND ENERGY CONSUMPTION. I. C. R. R. Suburban Service Train of Three [illegible] Cars.

On basis of [illegible] degrees C ultimate temperature rise for continuous performance of a run of 0.815 miles

Gross accelerating and braking rates 120 lbs. per ton.
Friction curve A Fig. 79 Date from curves Figs. 80 - 89.

Size of motor all cars motor cars	Total train Wt. loaded tons	Maximum speed M.P.H.	Schedule speed M.P.H.	Energy consumption Watt Hrs. ton mile	Power required Avg. K.W. per trai
2-100 H.P. per car	168	31	19.5	50	164
2-125 H.P. " "	171	36	21.0	59	212
2-150 H.P. " "	174	42	22.3	69	268
2-175 H.P. " "	176	48	24.0	81	343
2-200 H.P. " "	177	53	24.6	89	392
4-125 H.P. " "	183	55	25.1	96	426
4-150 H.P. " "	192	62	25.9	107	530

The table shows the very great increase in power required to obtain even a small increase in speed for the short run considered. By comparing the first and last equipments listed in the table, it is found that a 225 % increase of power is required to obtain a [illegible] % increase in schedule speed.

The data of Table IX, and the Armstrong curves when applied to this case are defective for the reason that the usual method of increasing the schedule speed on a short run, by using larger motors is to increase the rate of initial acceleration; rather than to keep accelerating rate constant, and increase the maximum speed. This is not meant to imply that the Armstrong curves are useless but that for such a comparison as is given in Table IX the results are a little misleading. (See page above) By a [illegible] % increase in power it is quite possible to obtain a [illegible] % increase in schedule speed on a run [illegible] miles by the expedient of increasing the accelerating rate from [illegible] lbs. gross to 160 lbs. gross per ton and cutting down the ultimate maximum speed in proportion. Mr. Armstrong himself has pointed out this point at various times—("Study of Heating of Railway Motors" A.I.E.E. June 1902.) A complete determination could be made if a set of these curves (Fig. [illegible]) were plotted for various rates of initial acceleration. And for short run rapid transit service, the rate of initial acceleration is such an important factor that it is inadvisable to compare motor equipments on the basis of a constant rate of initial acceleration being used.

[illegible] to the extent that the motors are worked well up towards the commutating limit during the acceleration or [illegible] period. This current is usually taken as the full load current on basis of the "one hr. rating", for non-interpole motors. The rate of initial acceleration for any train weight is therefore greater as the size of the motor is increased; since for short runs, it is not advisable to apply these motors in a manner to produce high maximum speeds.

There has been no little confusion regarding the exact significance of the rate of initial acceleration on schedule speeds and energy consumption. The term is often used without considering that it is no more a factor than is the speed to which this accelerating rate is carried. The problem is developed somewhat in detail in this Appendix and is an attempt to produce a rational solution on rational assumptions. Comparisons have been published on the basis of (1) constant rate of initial acceleration but also varying amperes per motor during accelerations, (2) on the basis of a constant percentage of speed on motor curve being reached, and coasting assumed variable in order to provide constant time for run; (3) or else that coasting is constant and time of run varies, percentage of motor curve reading also assumed constant. etc. etc.

It is difficult to reconcile a study of a motor made with these assumptions, with the actual manner in which a motor is applied and operated in service. The comparison by Mr. Armstrong is by far the most logical and if a set of curves for different accelerations could be

provided, the whole matter would be entirely complete and all that could be desired. That such a comparison has been made by Mr. Armstrong is strongly indicated in his recently published section, "Electric Traction", for the Standard Handbook in which, in Table of paragraph 126, different rates of acceleration are recommended depending on the length of typical run.

The problem is first one of train dynamics covering only the railway motor considered as a machine of certain speed torque relations; and second, one of limitations on motor output due to heating and commutation. The introduction of interpoles and forced ventilation has considerably reduced the problem to one of train dynamics only by permitting motor to be designed for the most economical speed torque relation without reference to limitations on output.

Dr. Cary T. Hutchinson has attempted the solution of the problem in the general case. Trans. A. I. E. E. Jan. 1902 "Relation of Energy and Motor Capacity to Schedule Speed" and more especially Trans. A. I. E. E. Oct. 1905 "Conditions governing the Rise of Temperature of Electric Railway Motors in Service". Applying the the methods to the case of the I. C. R. R. suburban trains, it is found that certain features of the method are inapplicable for the reasons given below.

1. The method of converting the type speed time curve of three constant accelerating rates a, b, and c, into a speed time curve having a portion of motor acceleration, is such that the new

speed time curve does not represent the same distance traversed; that is the through acceleration A is different in the two cases. This makes necessary an expensive calculation in order to determine the speed time curve with motor acceleration that corresponds with respect to distance traversed, with the type speed time curve. It is quite as difficult as determining the motor speed time curve at first without reference to the type speed time curve and its auxiliary curve sheets.

A decided ambiguity exists in an example in Mr. Hutchinson's [illegible] paper due entirely to this difficulty. The example on its face appears to be a complete solution of a run having schedule speed [illegible] M.P.H., distance 7000 ft. Time of stop [illegible] secs.; whereas the final results as worked out do not apply to this run but to one of less schedule speed and less distance.

2. Mr. Hutchinson's comparisons are based on a variable amount of coasting but with a constant percentage of motor curve running (up to speed 100 % on the motor speed curve, etc.). There is a question whether this should be the independent variable in these comparisons. The assumption of constant coasting time, with percentage of motor curve running being what it will, has always seemed to the writer a basis that more nearly represents actual service operation.

The problem worked out here is not intended to be a general solution, but is a particular one;- the determination of the best performance

of different sizes of motors for the I. C. R. R. suburban service typical run. The assumptions are only that

1. Length of Run is 0.815 miles
2. Coasting is constant, 10 seconds
3. Rate of braking is constant - net 1.6 M.P.H.P.S.
4. Current during acceleration on resistance notches shall be equal to full load one hour rating amperes.
5. All direct current motors of the non-interpole type have the same speed torque relations as regards percentage of full load absolute values.

These assumptions are all entirely admissable and correspond to actual operating conditions. It was deemed best to make this study based on a standard non-interpole motor design.

The use of interpole motors is likely to invalidate items 4 and 5 above. But a comparison on the basis of non-interpole motors should give a working estimate of service; and then if this can be bettered by using an interpole motor, then use it. The value of the study of non-interpole motors is in this manner no way lessened, since it provides data as to the very best possible performance of a non-interpole motor as a basis for comparison with an interpole design.

The assumption of constant coasting, 10 seconds, provides for the maximum power per run, and is in fact the manner in which motormen will operate the train. The necessary factor of safety to allow for making up time is provided by an increase of 8 % in time of run to obtain time table time.

Fig. 90 shows the general speed tractive effort curve that corresponds to standard motor designs. It is a basis for all the speed time curves to follow in this Appendix. The fact that one curve could be used for all standard motors was first pointed out by Dr. Hutchinson.

Figs. 91 to 97 incl. show the speed time curves for 100 typical run with various motor equipments ranging from 600 H.P. per three car train to 2400 H.P. per three car train, and in each case for varying rates of initial acceleration. It is noticed that for each particular motor equipment, there is a certain definite rate of acceleration that gives maximum schedule speed for the run. This is in line with the fact that if the rate of initial acceleration be halved, the speed to which it can be carried is practically doubled since the maximum rate of working is limited to only the one hour full load rating of the motor. The form of the curves illustrates the point very clearly. The curves are compiled with operating conditions as nearly like the I. C. R. R. suburban trains as is possible. That is, the train friction curve is taken from Fig. 8. the inertia of rotating parts is varied with the different sizes and gear ratios of equipment, and the total weight of train is varied according to the motor equipment used.

If it were only for dynamic reasons, the proper value of initial acceleration to use would be that providing minimum time for the run since in this way the greatest use is made of the size of motor. But limitations of output due to heating prevents in most cases the use of this rate of acceleration. A calculation has been made endeavoring

to show for each of the motor sizes of Figs. 91 to 97 how closely the heating limit affects the minimum time for run for each size of motor. The results are given in Fig. 98 in which that portion of the curves which are possible from a dynamic point of view but are impracticable on account of motor heating are shown dotted.

The extent of this influence varies according to the design of motor; that is, the amount of dotted lines in Fig. 98 depends on the particular motor used in estimating heating. In the calculations relating to Fig. 98, the following motors were used in estimating heating, -

100 H.P. size	Westinghouse No. 121
125 H.P. size	G E 66 D
150 H.P. size	Westinghouse No. 114
175 H.P. size	G E 88 C
200 H.P. size	G E 89 [illegible]

Comparing Fig. 98 with Fig. 6, it is apparent that a 20 % increase in schedule speed above presentservice can be provided only with 1400 H.P. in motors per 3 car train. This is with an initial acceleration of 1.15 M.P.H. per sec. Furthermore this equipment will provide a maximum speed on the Van Buren St., Hyde Park express run of about 50 M.P.H. It so happens that the initial rate of acceleration indicated as proper to use by this study, namely 1.15 M.P.H. per sec. corresponds with the 120 lb. gross per ton of the Armstrong Curves of Figs. 79 to 90, and also with the statement in paragraph 126 of section "Electric Traction" of the Standard Handbook that the proper rate of

acceleration on a run of one stop per mile is 1.10 M.P.H. per sec. This latter item is a good check on the result.

The necessary equipment is best provided by two nominal 200 H.P. motors which when accelerating at 340 amperes and 570 volts will furnish 1400 H.P. per three car train as maximum net output at end of initial accelerating period.

APPENDIX [illegible]

COMPARISON OF G E 69 C MOTOR WITH G E 69 B MOTOR FOR I. C. R. R. SERVICE.

The G E 69 C motor as supplied to the New York Central Electric zone for suburban trains and to the West Jersey and Sea Shore, Camden to Atlantic City branch is of different electrical design than the G E 69 B motor as supplied to the Interborough Subway and Metropolitan District Ry. The G E 69 C motor has more field and armature turns and hence operates at slower rotative speeds (see Fig. 21A). The advantage of this design is that core loss, which is an important heating factor in long runs, is lower than in the G E 69 B motor. This is due to the decreased rotative speed. To attain this end the copper loss is higher, but in long run service this loss is comparatively less important since the time the motor is being accelerated is relatively small. The magnitudes of these various losses are well shown in Figs. 22 and 23.

Fig. 21 shows dimensions of the G E 69 C motor, Fig. 19 shows characteristic curves and Fig. 20 the general speed tractive

effort curve. A comparison of this motor with the G E 69 B shows that the G E 69 C motor with a gear ratio 1.78 will duplicate the perfromance of the G E 69 B gear ration 2.46 as far as speed is concerned. Fig. 22 shows a typical run with gear ratio 1.76. Although the core losses are lower, the copper losses are so much higher that the heating is excessive, being 15 degrees Cent. higher in service than the G E 69 B motor would be. Fig. 23 shows a typical run with gear ratio 1.78 but with a reduced accelerating current. The time for the run is increased 2 % but even with this reduction of copper losses, the temperature is still higher in service than would be the temperature of the G E 69 B motor. The average length of run must exceed 1.25 miles before the G E 69 C motor will operate at less temperature than will the G E 69 B motor.

APPENDIX [illegible]

METHOD OF OPERATION OF MOTOR CONTROL DURING INITIAL ACCELERATION.

Messrs. Parshall and Hobart in their work "Electric Railway Engineering" page 63 et seq. have developed a series of interesting studies of motor acceleration in which a considerable saving of energy is shown due to permitting the motors to operate on the "motor curve" for an interval between the series and parallel controller positions. It is of interest to inquire what possibilities for saving of energy occur from this method in the present instance.

The curves Figs. 99 to 107 incl. are developed after the manner shown by Parshall and Hobart but it is to be observed that they relate to the use of automatic control with limit switch set at a certain definite value. In this way the group of curves is perhaps more applicable to modern conditions than is the series worked out by the above writers.

There is a slight decrease in the average rate of initial acceleration; but this, in the case of the I. C. R. R. suburban trains will merely decrease the schedule speed an average of 1 %. There is however a considerable saving of energy totaling 8.0 %. This is due to, - first, less time on parallel resistance notches; second, lower values of parallel resistance grids; third, lower motor losses.

Table [illegible] shows in detail the average losses and percentages as compiled from Figs. 99 to 107. The figures under columns headed

[illegible] obtained

[illegible] method of control.

TABLE XXI.

COMPARISON OF TWO METHODS OF CONTROL
G E 69 B MOTORS - 570 VOLTS.

	Method I.		Method II.	
	To full parallel	For typical run 0.815 Miles	To full parallel	For typical run 0.815 miles
Distance miles	0.0714	0.815	0.089	0.815
Time seconds	18.5	106	23	107
Energy, K.W. Hrs. per car at 570 volts	1.73	4.45	1.61	4.05
Percentage		100		92
Armature copper Loss per motor in Watt hours	24.0	36.2	236.	34.0
Percentage		100		94
Armature Core Loss per motor Watt Hrs.	8.0	57.7	10.3	55.3
Percentage		100		96.2
Combined Loss	[illegible] K.W. Hrs		[illegible] K.W. Hrs.	
Percentage		100	69	

This method of control can be furnished by means of a trip on the limit switch that will delay the progression of the limit switch between series and parallel positions until the current per motor falls to below 170 amperes. Such a device could be easily made and would cause practically no added complication or cost to the control apparatus.

APPENDIX E.

METHOD OF OBTAINING SUB STATION LOAD CURVES OF FIGS. 46 TO 59 INCLUSIVE.

The substation load curves are obtained by determining from the provisional schedule sheet, Fig. 44 the number of cars passing any substation during each half hour of the day. The average load per car per substation was determined from the power time curves of the separate runs as recapitulated in Fig. 27. It is assumed that the total current to a train is derived from the two adjacent substations in a ratio inversely proportional to the respective distances from the sub stations to the train. This is strictly true when only one train is operating between sub stations. In the actual case of several trains between sub stations, it is more nearly true than is the assumption that there is an arbitrary mid point beyond which one sub station does not feed toward the other.

It is further assumed that the performance of a car in a three car train is typical of the performance of an average car of the service; that is, no allowance is made for the slightly less energy per car of a 5 car train, or the slightly greater energy per car of a one car train.

Table XXII shows these unit loads per car per substation as derived in the manner shown above: -

[illegible]

UNIT LOAD ON SUBSTATIONS SHOWING LOAD PER CAR PER SUB STATION FOR DIFFERENT CLASSES OF SERVICE.

G E 69 B MOTORS 600 VOLT SYSTEM

Gear Ratio 2.46 36 in. wheels

Sub station	One Car of Following Service	At Third Rail K.W. Hrs. at 570 volts Power	Power Light	Power Light Heat	P.	At Sub station K.W. Hrs. at 630 Volts P. and L.	P. L. and H.
No.1-12th St.	Local	[illegible]	17.4	19.6	18.7	19.2	21.6
	Express	13.80	14.1	[illegible]	[illegible]	15.6	17.6
No.2-Oakland	Local	21.3	21.8	24.4	23.5	24.1	27.0
	Express	8.2	8.4	9.2	8.9	9.2	10.1
No. 3-Woodlawn	Local	9.1	9.3	10.5	10.0	10.3	11.6
	Grand X Ex.	17.6	18.1	20.6	19.7	20.2	23.0
	B.I. & F. Ex.	21.1	21.6	24.2	23.3	23.9	25.6
	So. Chgo. Ex.	15.3	15.7	17.6	17.0	17.4	19.5
No.4-Burnside	Grand X Ex.	2.0	2.1	2.4	2.3	2.4	2.7
	Flossmoor Ex.	19.7	[illegible]	[illegible]	[illegible]	22.3	25.0
	Blue Is. Ex.	31.7	32.5	36.4	33.9	36.9	40.2
No.5-Riverdale	B.I. Ex.	12.0	12.3	13.8	13.3	13.6	15.3
	Flossmoor Ex.	22.3	22.8	25.6	24.6	25.2	28.3
No.6-Homewood	Flossmoor Ex.	18.7	19.2	21.5	20.7	21.2	23.8
No.7-Windsor Pk.	So.Chgo. Ex.	22.3	[illegible]	[illegible]	23.6	25.3	25.8

In the above table, 5 K.W. Hr. per car has been added to the substation unit load in case terminal switching is necessary. Lighting and heating of stored cars at 12th St. and other termini is assumed to begin 30 minutes before the cars are placed in service. This load is added to the load as determined for cars in operation only.

[illegible]

STORAGE BATTERIES AT SUB STATIONS 600 VOLT DIRECT CURRENT SYSTEM

The advantage of storage batteries for this service consists in

1. Reduction of rotary converter capacity due to elimination of effect of swings at convertor, flatter load curve possible, and less reserve machinery.

2. Reduction in cost of high voltage lines due to elimination of swings and to less necessity for duplicate lines.

3. Reduction in power house capacity.

4. Saving in cost of power if purchased on a maximum demand basis.

5. Operation of trains maintained in event of failure of transmission lines.

To obtain a definite idea as to the amount of fluctuation on a substation, there has been calculated Fig. 108. This is an exact load curve on 12th St. sub station from 5:30 P.M. to 5:50 P.M. during a summer week day rush hour with trains operating according to the provisional schedule of Fig. 44. It is obtained by adding together the instantaneous loads of the various trains for the period in consideration.

Assuming batteries to be used at this sub station and that the converters supply 3000 K.W. continuously during the interval, then the battery must provide 4000 K.W. for one minute or a 5000 K.W. peak of 15 secs. This will be the maximum demand in this battery.

Such a battery would be rated at about 4000 amperes on a one hour discharge basis, or for 8 hr. discharge rate at about 900 amperes.

The addition of this battery would necessitate the operation of but 2 - 1000 K.W. convertors during the rush hour. They would be carrying a steady 25% overload but their operations at this load would be better than that of 3 - 1000 K.W. units carrying an average load of 2500 K.W. but with fluctuations from 1000 K.W. to 3500 K.W. Similarly during the middle of the day, it would be necessary to operate but one converter instead of two in the case of batteries not being used. The battery therefore dispenses with the operation of one 1000 K.W. converter.

The purchase of power from the Commonwealth Edison Company is a strong probability for this case. The rate would be about 0.5 c per K.W. hr. with a maximum demand rate of $15.00 per year per K.W. of 5 minute peak. The 5 minute maximum demand from this substation occurs from 5:40 to 5:45 P.M. when it is 4700 K.W. in summer and 5100 K.W. in winter.

It is unlikely that this demand will be coincident with the maximum demand on other sub stations, so that on the basis of cutting down maximum demand in case power is purchased, the 4000 amp. 1 hr. rate battery will not be of much use. The general conclusion is that since all cycles of fluctuation of load during rush hour are less than 5 min. duration, the use of batteries of just sufficient capacity to

eliminate fluctuations will not decrease the 5 minute demand from the company supplying power.

To produce any effect on the 5 min. maximum demand, it is necessary to introduce additional battery capacity above that required to eliminate fluctuations. Furthur, every extra Kilowatt so added will decrease the maximum demand by an amount just equal to this added capacity.

Applying these conclusions to the various sub stations, it is necessary to instal battery capacity of the amounts shown in the following Table XXIII in order that the full benefit of the 5 minute maximum demands can be attained. This equipment is also chosen so that maximum permissable charge rates in all day service will not be exceeded. The table also shows the alternative equipment, and probable coincident maximum demands, in case batteries be not installed.

TABLE XXIII.

[illegible]
WITH AND WITHOUT BATTERY
600 VOLT SYSTEM

(A) WITHOUT BATTERY

Sub Station	Rotary Capacity K.W.	5 minute Probable coincident maximum demand K.W.	20 sec. maximum Demand K.W. (winter)
12th Street	4-1000	3500	8900
Woodlawn	4-1000	3800	7900
Oakland	4-1000	3800	7300
Burnside	3-1000	1800	5250
Riverdale	3-1000	900	4300
Homewood	3-1000	700	2380
Windsor Park	3-1000	900	4600
Totals	[illegible]	[illegible]	

(B) WITH BATTERY

			Battery capacity one hr. Rate
12th Street	3-750	2000	4000 Amps.
Oakland	3-750	2000	3400
Woodlawn	3-750	2000	3400
Burnside	3-500	1000	2000
Riverdale	2-500	600	1800
Homewood	2-500	400	1000
Windsor Park	2-750	750	1800
Totals	15000	6750 K.W.	17400 Amp. Hrs. at 630 volts

In each of the above cases add to the maximum demand 1400 K.W. for losses and auxiliary supply. Items of specifications that determine size of battery at various sub stations are given below:

12th St:- Battery capable of taking 20 sec. peaks of 11200 amperes after it has been discharged 2800 amp. hrs. at mean rate of 2500 amperes.

Oakland:- 20 sec. peak of 8600 amps. after discharge of 2700 amp. hrs. at mean rate of 2500 amperes.

Woodlawn:- 20 sec. peak of 9400 amps. after discharge of 2300 amp. hrs. at mean rate of 2500 amperes.

Burnside:- 20 sec. peak of 6700 amps. battery full charged.

Riverdale:- 20 sec. peak of 5900 amps. battery full charged

Homewood:- 20 sec. peak of 3200 amps. battery full charged

Windsor Park:- 20 sec. peak of 6100 amps. battery full charged.

Following is a comparison of cost of equipment with and without batteries, on basis of power purchased from Commonwealth Edison Co.

WITHOUT BATTERY

Rotary converter and step down Trans. etc.	$ 810,000
7 sub station bldgs.	36,000
Capital in sub stations	$ 846,000
37.4 miles 3 phase line 2/0 cable	240,000
Capital Power distrib. Acct.	$ 1,086,000

WITH BATTERY

Rotary converter and step down Trans.	$ 530,000
7 Sub station Bldgs.	48,000
17400 amp. hr. (1 hr. rate battery) with boosters and switch gear	790,000
Capital in sub stations	$ 1,368,000

57 miles 3 phase line No. 1 cable	$ 210,000
Capital for Power Distrib. Acct.	$1,578,000

In the following there is a comparison of the annual cost of power for the two cases.

WITHOUT BATTERY

5 % capital	$ 54,300
5 % Dep. Elec. equipment of sub stations	40,500
3 % Dep. lines & overhead work	7,200
	$ 102,000
1[illegible] K.W. maximum demand at $1[illegible]	[illegible]
46 486 000 K.W. hrs. at 1/2 cent	232,430
Annual Power Charge	$ 386,430

WITH BATTERY

5 % Capital	$ 79,400
5 % Dep. Elec. equip. of sub station	26,500
3 % Dep. Lines	6,300
10 % Dep. Batteries	79,000
	$ 191,200
10 150 K. W. max. Demand at $15.00	152,250
46 486 000 K.W. hrs. at 1/2 cent	232,430
Annual Power Charge	$ 575,880

It appears therefore that the use of storage batteries will give scarcely any decided saving in annual charges, even if power be purchased. If the company builds its own power house, the maximum demand charge would be nearer $12.00 a year per K.W. and the works cost about 0.6 c instead of 0.5 c per K.W. hr. This would throw the balance in favor of an installation without batteries. The estimate above, which shows an apparent saving of $11000 per year with batteries, is not sufficiently precise to warrant the adoption of storage batteries in sub stations on the basis of this estimate alone.

With storage batteries, the regulation of the high voltage system will be superior to that of the system without batteries, even though the conductors are of smaller size. Also, the storage batteries will permit, in case of accident, a complete shut down of one hour during rush hours; or of 2 hours during the middle of the day.

It is the writer's opinion that with a well constructed system, the liability of such shut down is very remote; and that the regulation without batteries is sufficiently good for the service (See page 62). It is exceedingly desirable from the standpoint of the railroad company to cut down the first cost, and a saving in this item of $467,000 can be effected if storage batteries be dispensed with.

If the railroad should build its own power house, it would be better to omit batteries; if it purchases power, the desirability of storage batteries is still indeterminate. Later if extension for main line terminal traffic is contemplated, the increased load thus occasioned can be met most satisfactorily by the addition of storage batteries to the then existing sub stations.

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON

FIGURE No.________

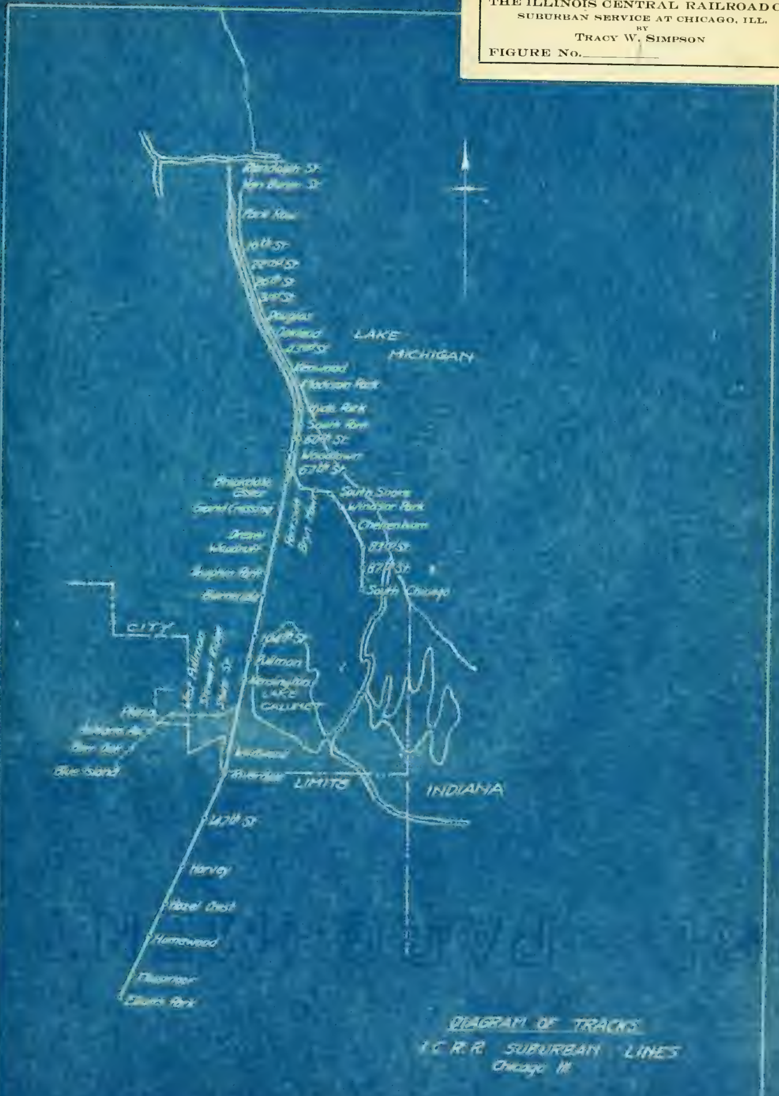
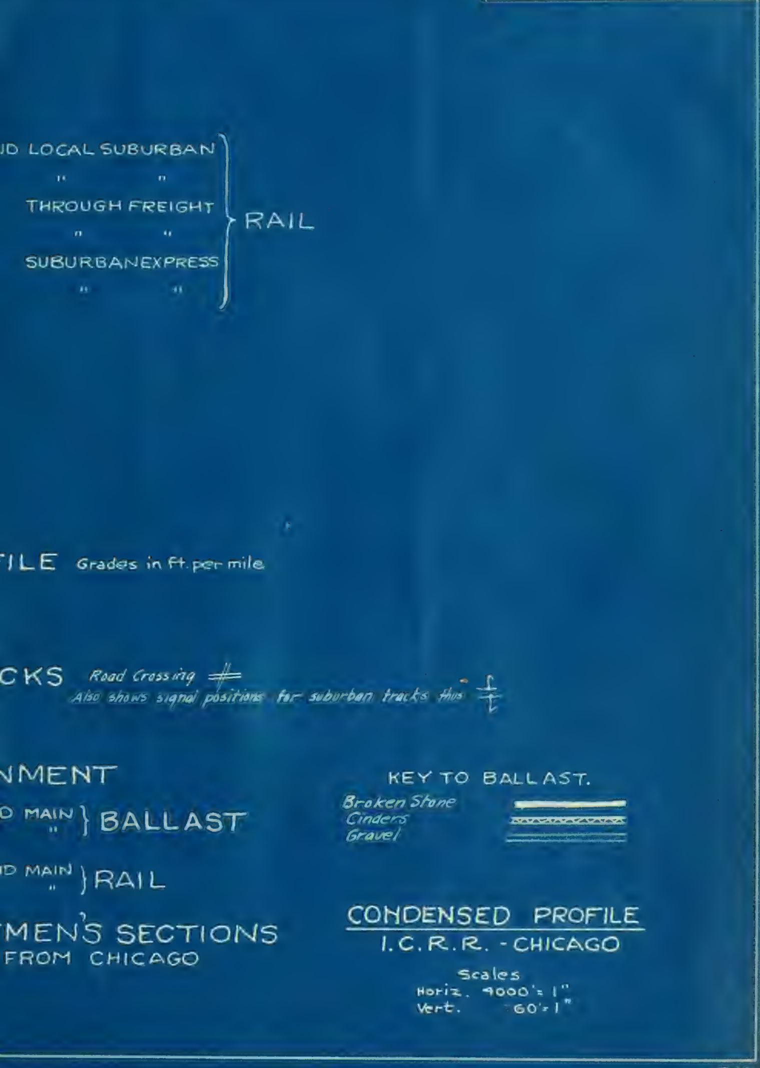


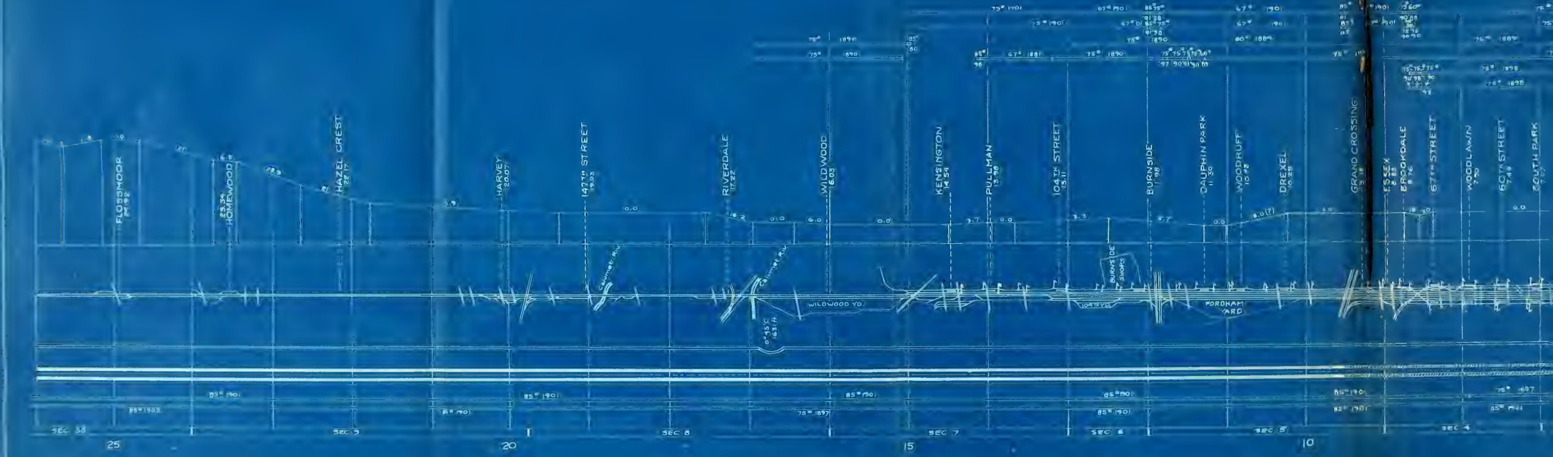
DIAGRAM OF TRACKS
I.C.R.R. SUBURBAN LINES
Chicago Ill

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD C
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. ______

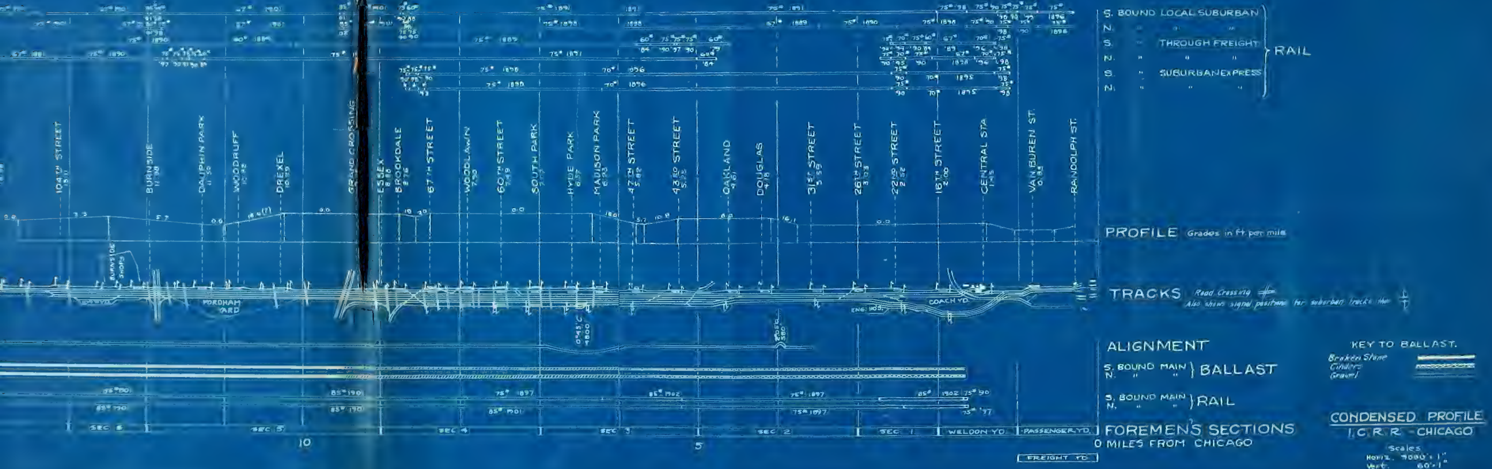


CONDENSED PROFILE
I.C.R.R. - CHICAGO

Scales
Horiz. 4000' = 1"
Vert. 60' = 1"


FLOSSMOOR 24.92
23.34 HOMEWOOD
HAZEL CREST 22.17
HARVEY 20.07
147TH STREET 19.03
RIVERDALE 17.22
WILDWOOD 6.03
KENSINGTON 14.54
PULLMAN 13.98
104TH STREET 13.11
BURNSIDE 11.98
DAUPHIN PARK 11.30
WOODRUFF 10.42
DREXEL 10.29
GRAND CROSSING
ESSEX
BROOKDALE 8.76
67TH STREET
WOODLAWN 7.50
60TH STREET 7.49
SOUTH PARK
CALUMET RIV
CALUMET RIV
WILDWOOD YD
104TH YD
BURNSIDE SHOPS
FORDHAM YARD
0.0
3.9
0.0
16.2
0.0
6.0
0.0
3.7
0.0
3.3
5.7
0.0
8.0(?)
0.0
0.0
75# 1890
75# 1890
75# 1901
67# 1901
85# 75#
67# 1901
75# 1901
67# 1881
75# 1890
80# 1889
75# 1889
75# 1898
85# 1901
85# 1902
85# 1901
85# 1901
85# 1901
75# 1897
85# 1901
85# 1901
85# 1901
85# 1901
75# 1897
85# 1901
SEC 53
SEC 9
SEC 8
SEC 7
SEC 6
SEC 5
SEC 4
25
20
15
10

THE ILLINOIS CENTRAL RAILROAD
SUBURBAN SERVICE AT CHICAGO ILL.
BY
TRACY W. SIMPSON
FIGURE No.



ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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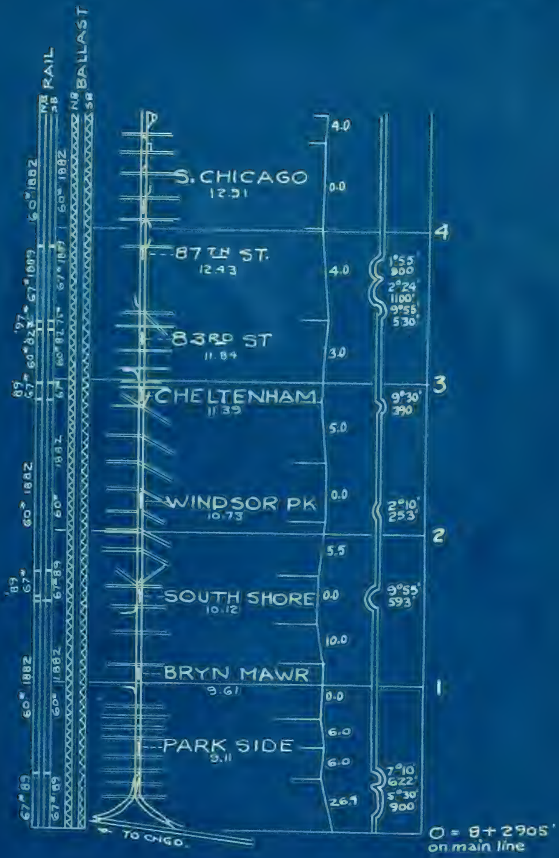
FIGURE No. 3

CONDENSED PROFILE
SO. CHGO. BRANCH



ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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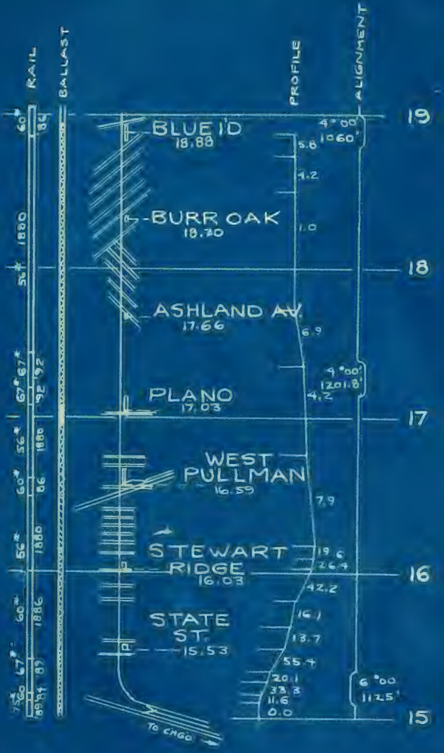
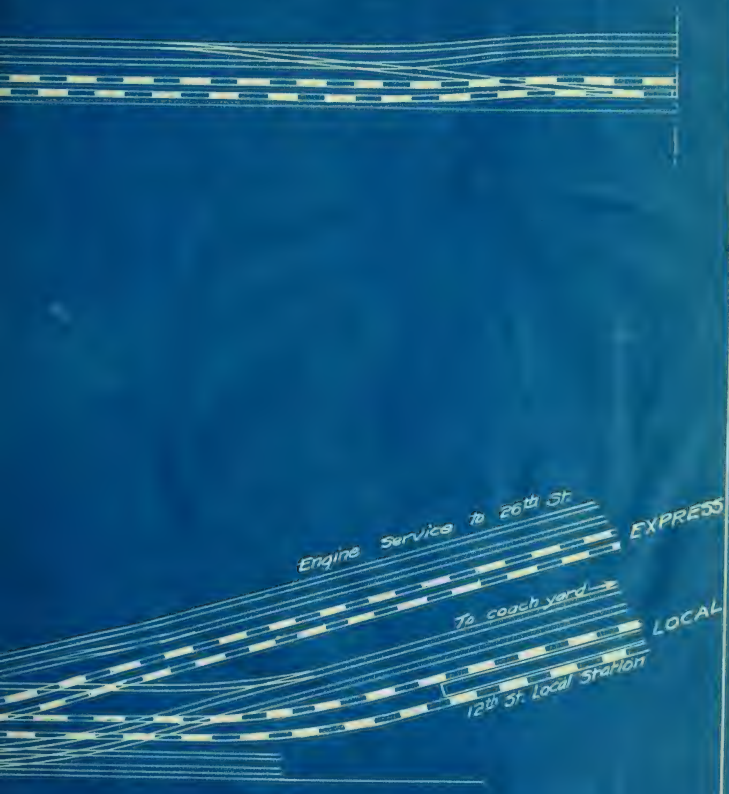
FIGURE No. 4



CONDENSED PROFILE-ETC.
BLUE ISLAND BR.

T.W.S.

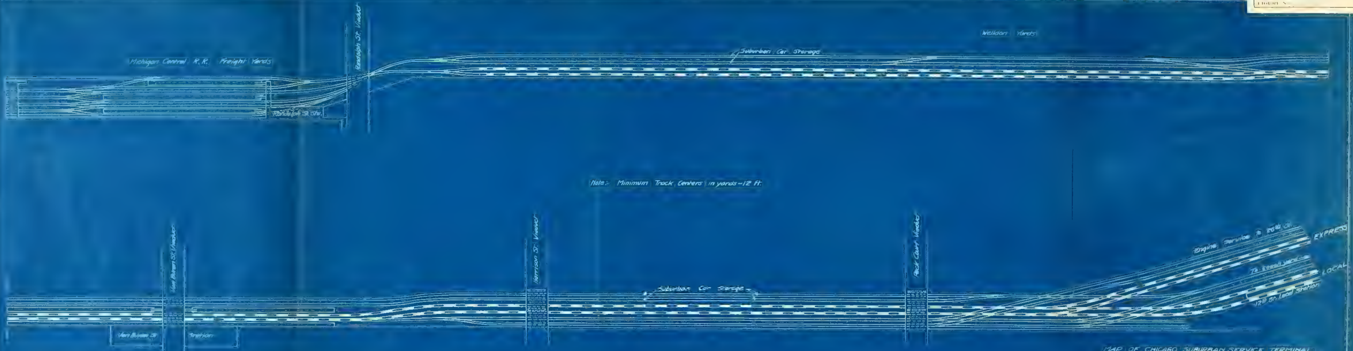
ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 5



MAP OF CHICAGO SUBURBAN SERVICE TERMINAL.
ILLINOIS CENTRAL RAILROAD

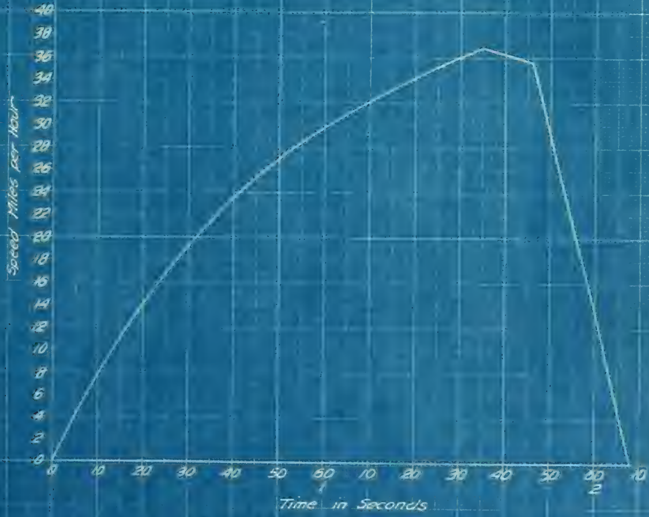
Scale; 1in. = 1000 Ft.

T.W.S.



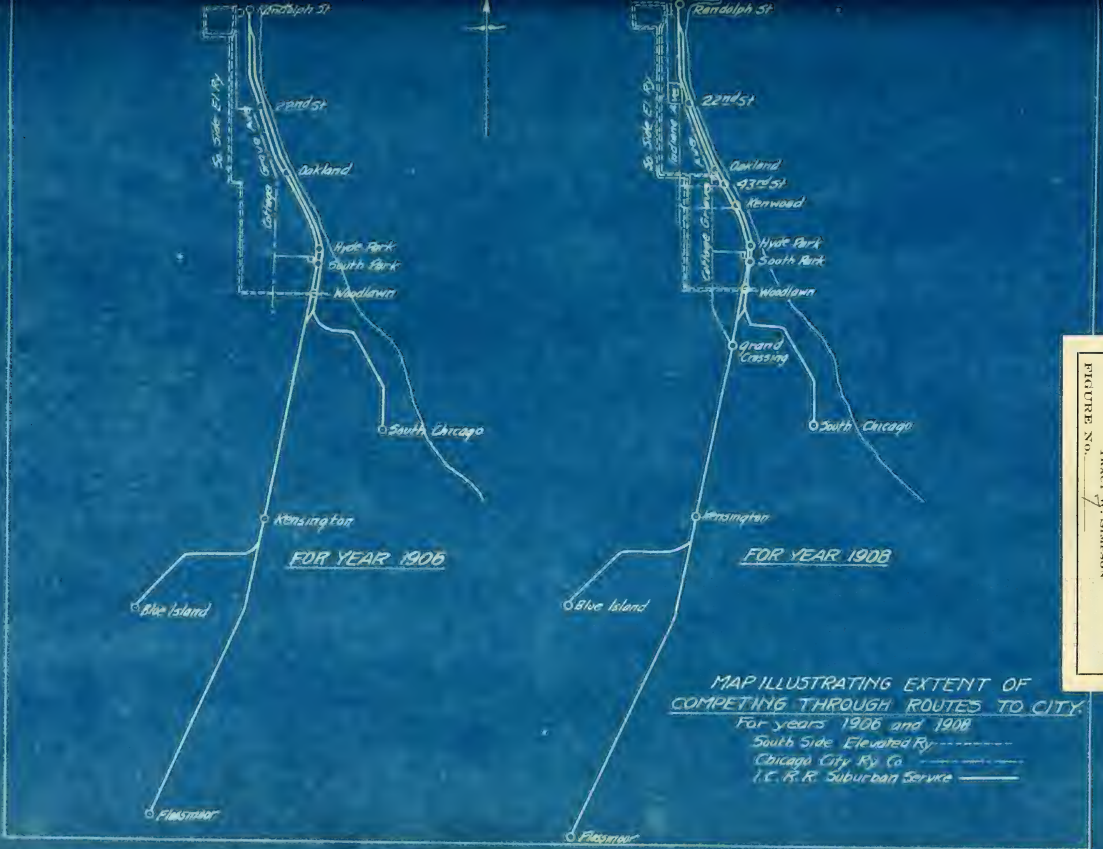
MAP OF CHICAGO SUBURBAN SERVICE TERMINAL.
ILLINOIS CENTRAL RAILROAD.
Scale; 1 in. = 1000 ft.

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. ______



TYPICAL RUN 0.815 MILES
Type 2-6-4 - Locomotive - 3 Side Door Cars
Total Train Weight 207 tons
Estimated best performance

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 7

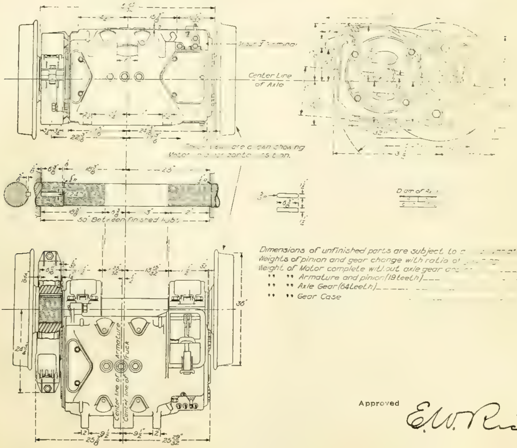


MAP ILLUSTRATING EXTENT OF
COMPETING THROUGH ROUTES TO CITY
For years 1906 and 1908

South Side Elevated Ry - - - - - - - -
Chicago City Ry Co — - — - —
I.C. R.R. Suburban Service ————

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 9

GE-69-B MOTOR SUSPENSION



Dimensions of unfinished parts are subject to [illegible]
Weights of pinion and gear change with ratio of [illegible]
Weight of Motor complete without axle gear and [illegible] ---- [illegible] Lb
" " Armature and pinion (19 teeth) --- 708 "
" " Axle Gear (64 teeth) ---- 41[illegible] "
" " Gear Case 22[illegible] "

Approved E.W. Rice Jr.
Chief Engineer

FOR REFERENCE ONLY unless endorsed on back.

28 Nov. 1905

ENGINEERING DEPT.
GENERAL ELECTRIC COMPANY

No. 14214

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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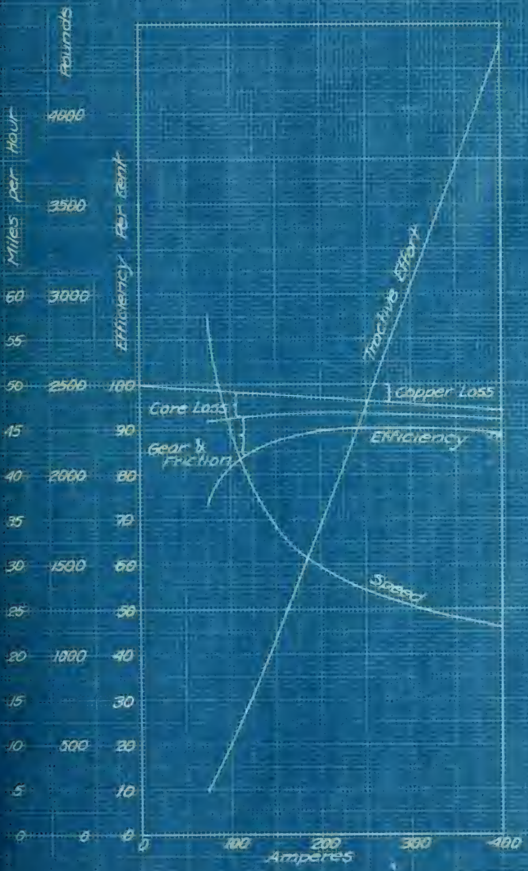
FIGURE No. 10



GE 69 RAILWAY MOTOR
Arm. Spec 15822 Field Spec F 7020-1
Characteristic Curves
570 Volts 36in. Wheel
Gear Ratio $\frac{59}{24} = 2.46$

Speed Curve corrected to 75°C

TWS

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THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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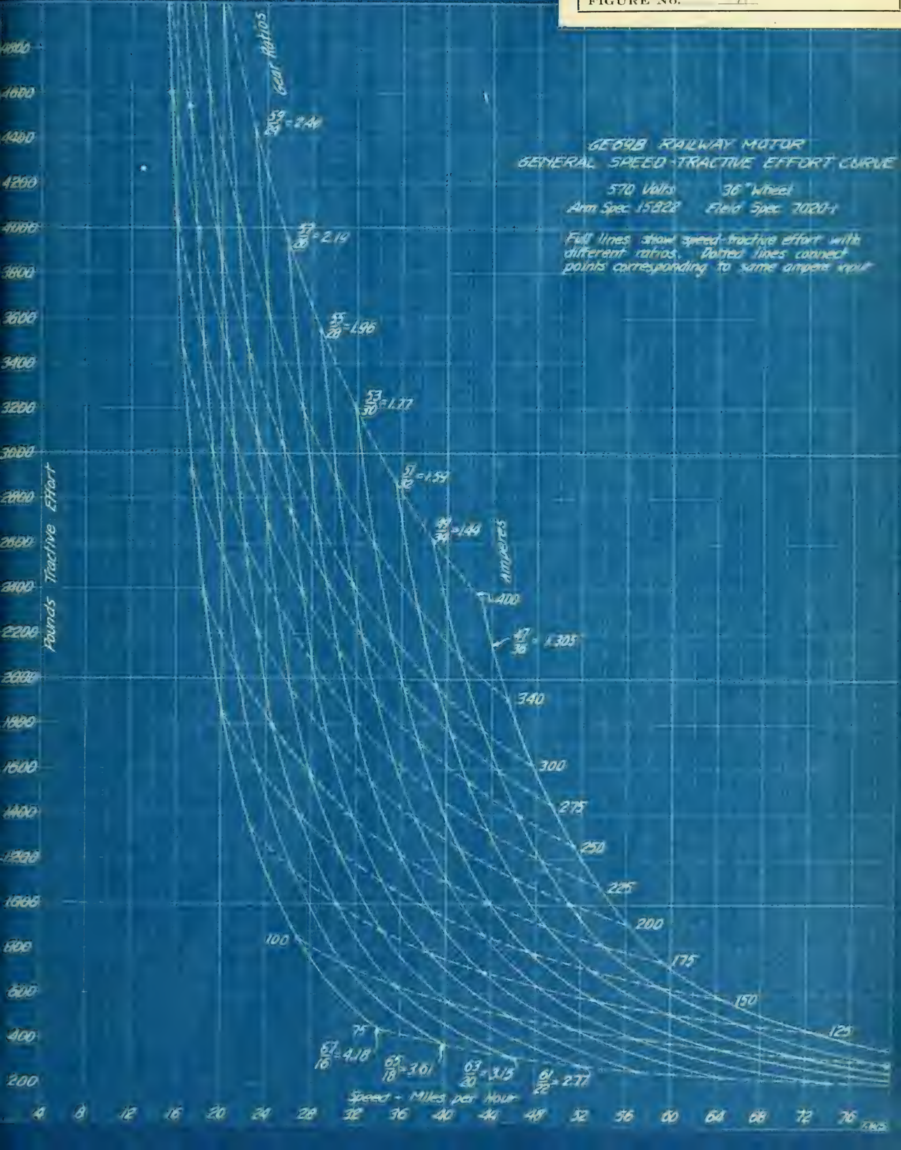
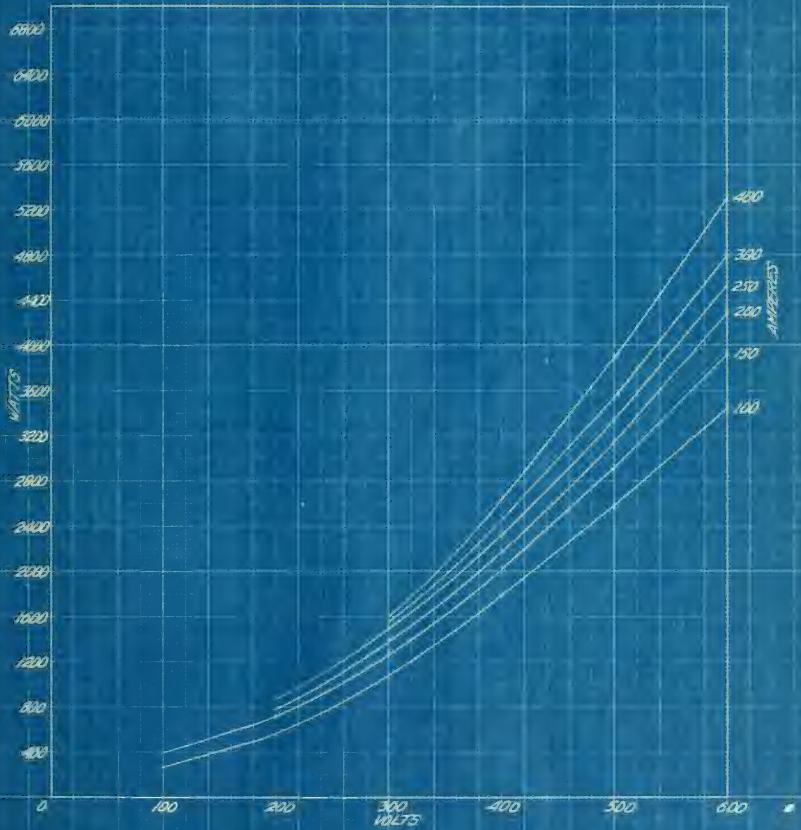
FIGURE No. 11



ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 12

ELECTRIC RAILWAY ENGINEERING DATA BOOK.
Part Sheet No

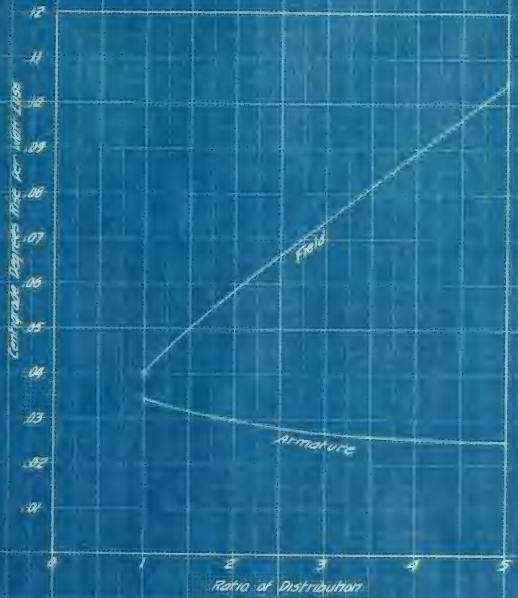
Compiled by T.W. Simpson Chicago Ill



GE69 RAILWAY MOTOR.
1 TURN ARM.
Arm Spec 15822 Field Spec 2020-1

CORE LOSS CURVE.

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 13



GE 69 Railway Motor
Approx. Thermal Capacity Curves-25 MPH
Perforated covers on ventilating openings

T.W.S.

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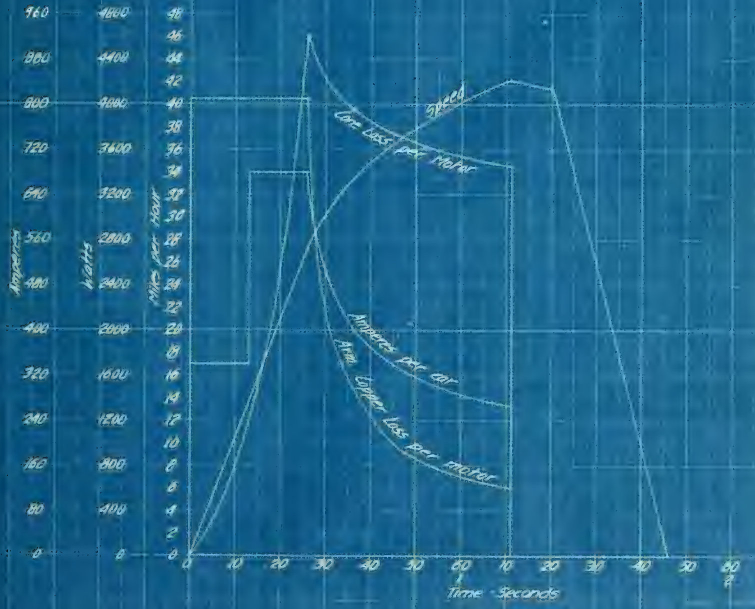
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 17

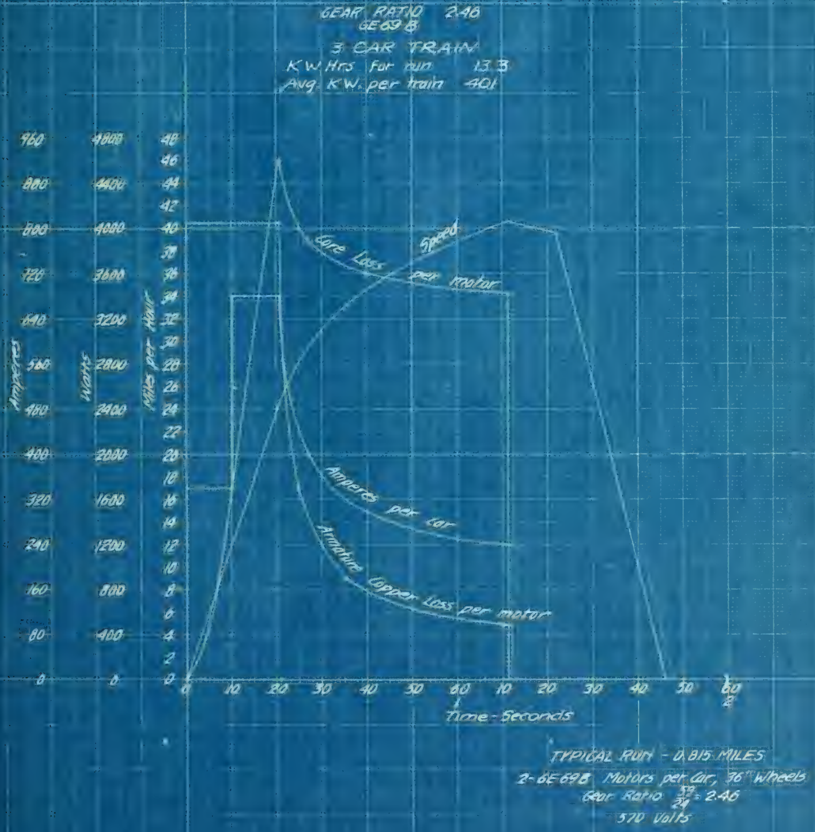
GEAR RATIO 2.19



TYPICAL RUN 0.815 MILES
2 GE 69B Motors per Car 36" wheels
Gear Ratio $\frac{57}{26}$ = 2.19
570 Volts

T.W.S.

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 5


GEAR RATIO 2.46
GE 69 B
3 CAR TRAIN
K.W. Hrs for run 13.3
Avg. K.W. per train 401

TYPICAL RUN - 0.815 MILES
2-GE 69 B Motors per Car, 36" Wheels
Gear Ratio $\frac{59}{24} = 2.46$
570 Volts

T.W.S.

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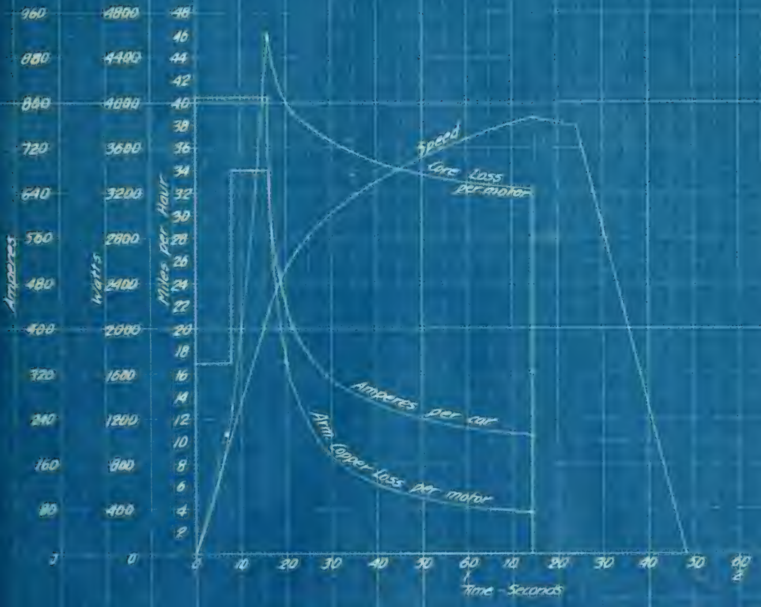
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 16

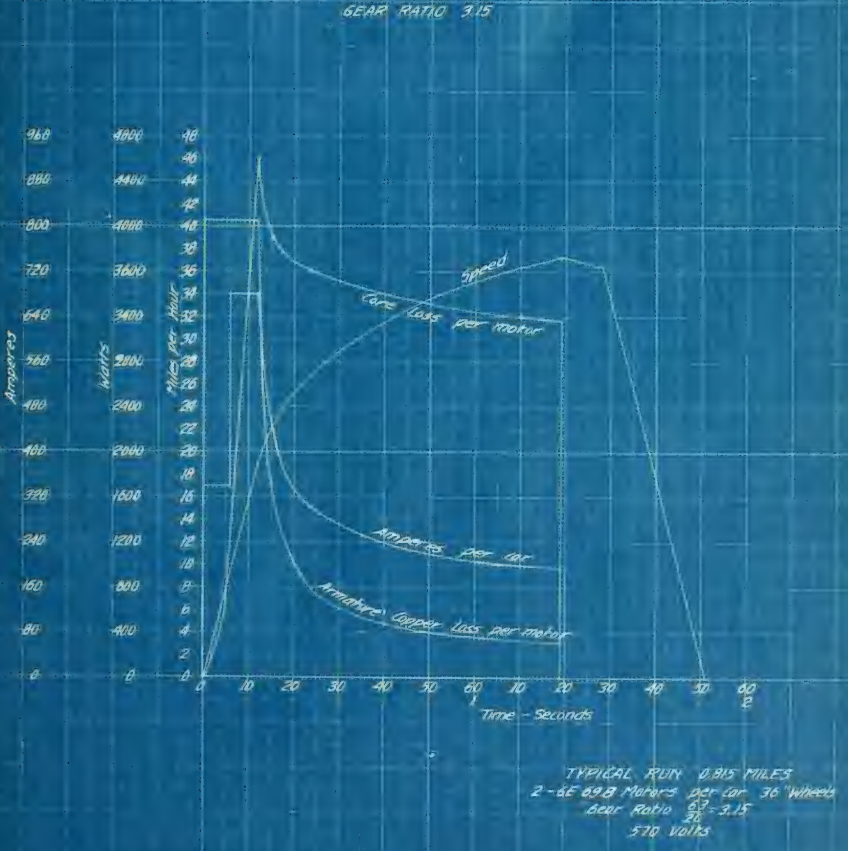
GEAR RATIO 2.77



TYPICAL RUN - 0.815 MILES
2 GE 69B Motors per car 36" Wheels
Gear Ratio $\frac{61}{22}$ = 2.77
570 Volts

TMS

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
Tracy W. Simpson
FIGURE No. 17



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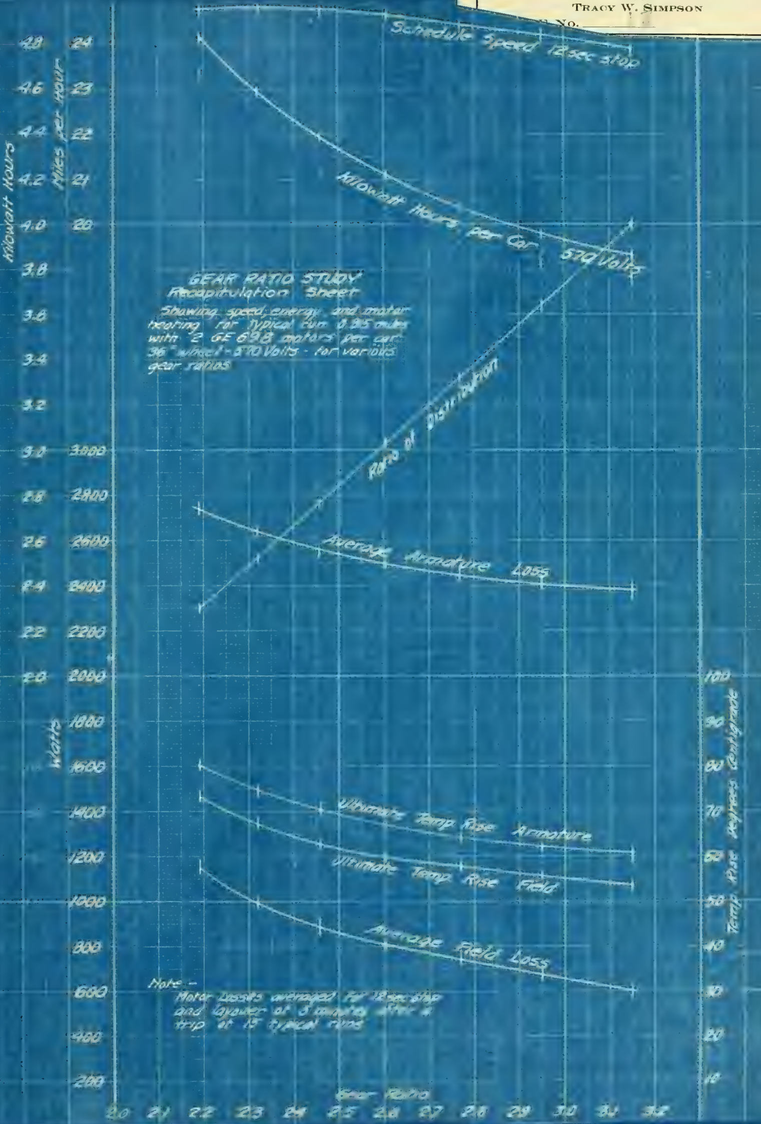
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
No.



GEAR RATIO STUDY
Recapitulation Sheet
Showing speed, energy, and motor heating for typical run 0.85 miles with 2 GE 69 B motors per car 36" wheel - 570 Volts - for various gear ratios

Note -
Motor Losses averaged for 12 sec stop and layover of 3 minutes after a trip of 15 typical runs

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BY
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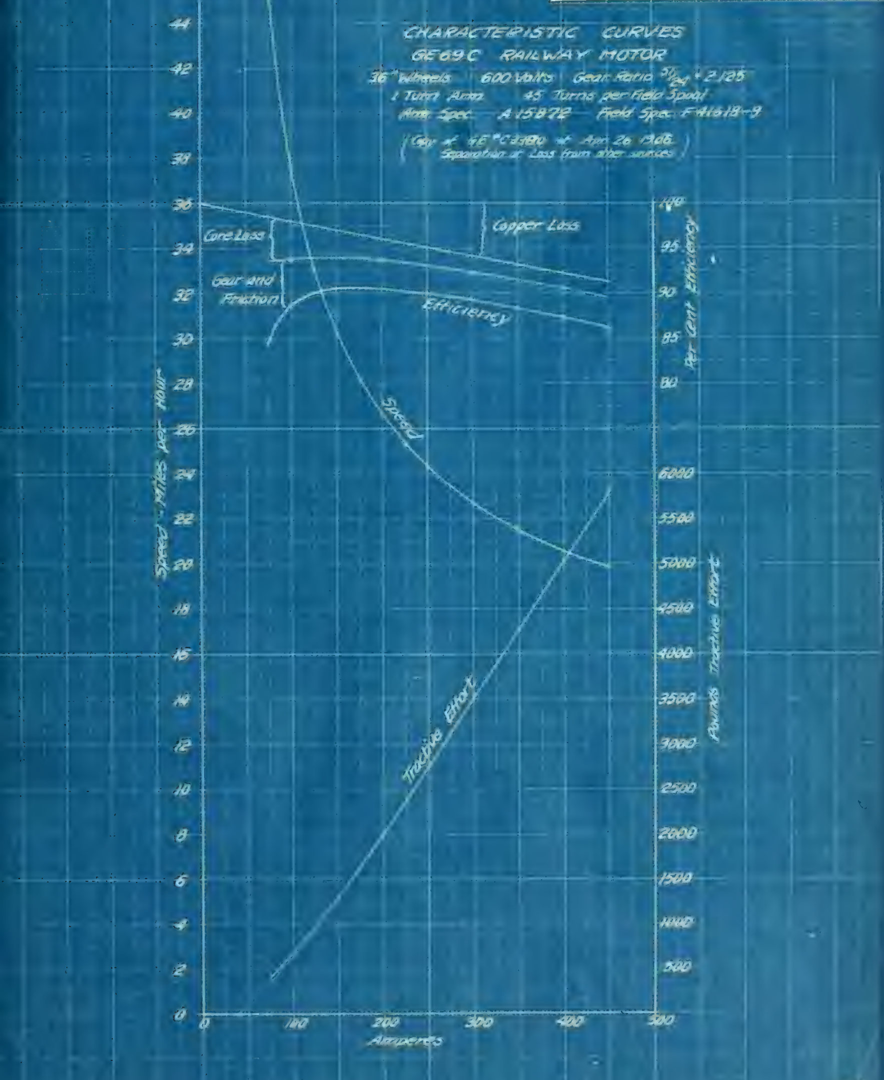
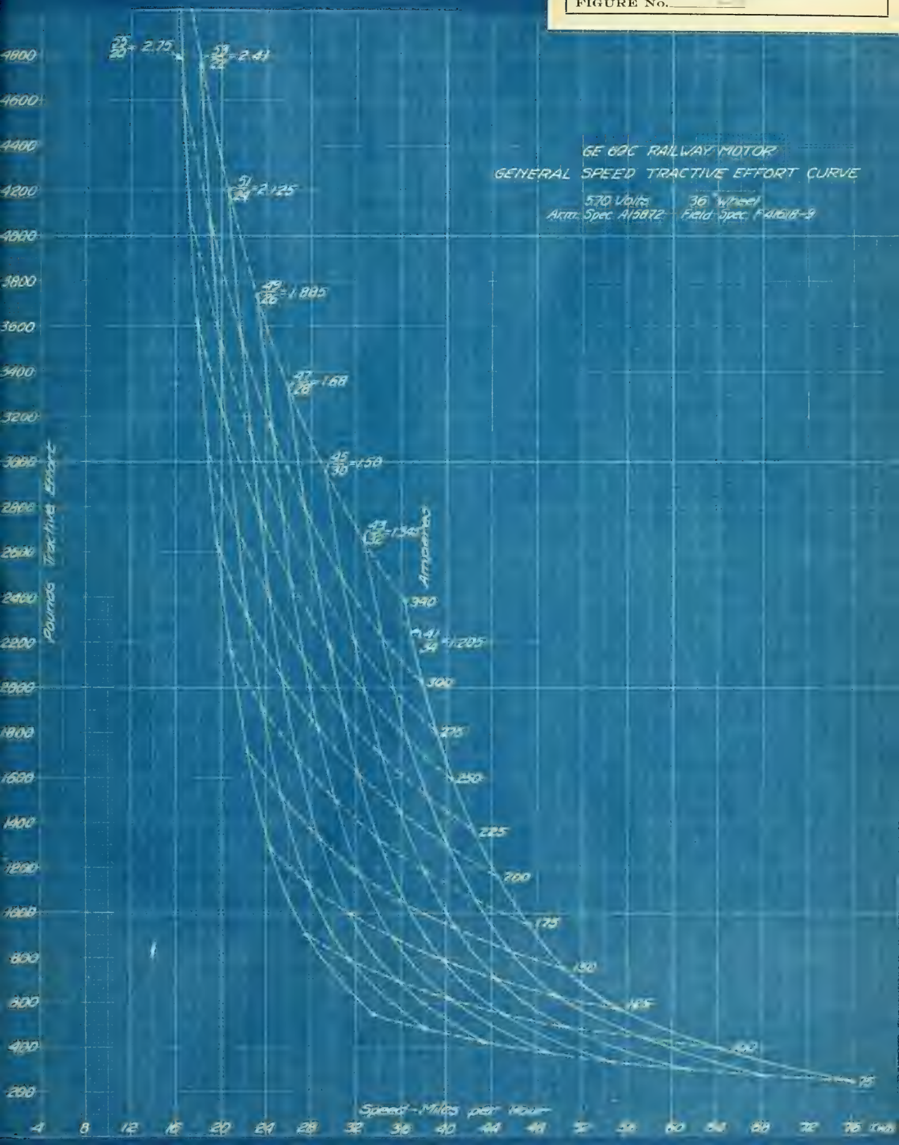
FIGURE No. 2



ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No.________



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THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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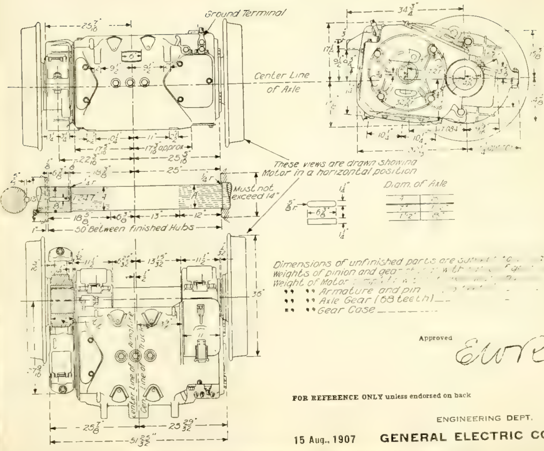
FIGURE No. 21

DIMENSIONS OF GE 69-C MOTOR



Dimensions of unfinished parts are [illegible]
Weights of pinion and gea[illegible]
Weight of Motor [illegible]
" " Armature and pin [illegible] 420 "
" " Axle Gear (68 teeth) [illegible] "
" " Gear Case [illegible]

Approved E W Rice Jr. Chief Enginee

FOR REFERENCE ONLY unless endorsed on back

ENGINEERING DEPT.

15 Aug., 1907 GENERAL ELECTRIC COMPANY No. 14339

ELECTRIFICATION PROJECT
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SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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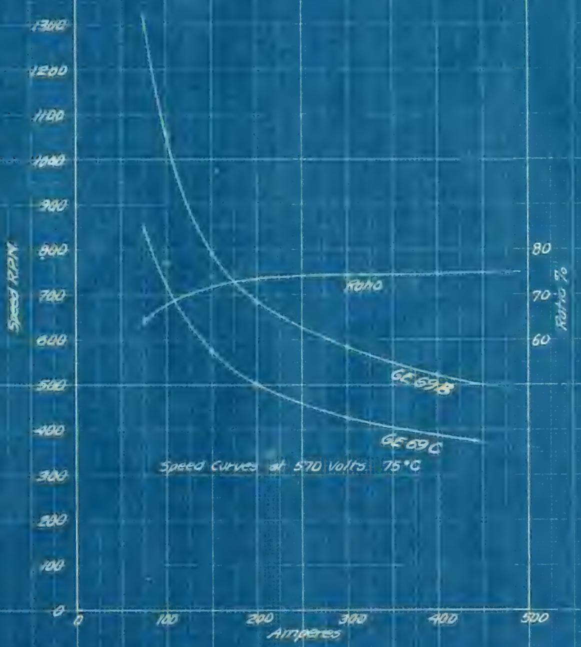
FIGURE No. 21A



COMPARISON OF SPEED CURVES
GE69B RAILWAY MOTOR
GE69C RAILWAY MOTOR

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BY
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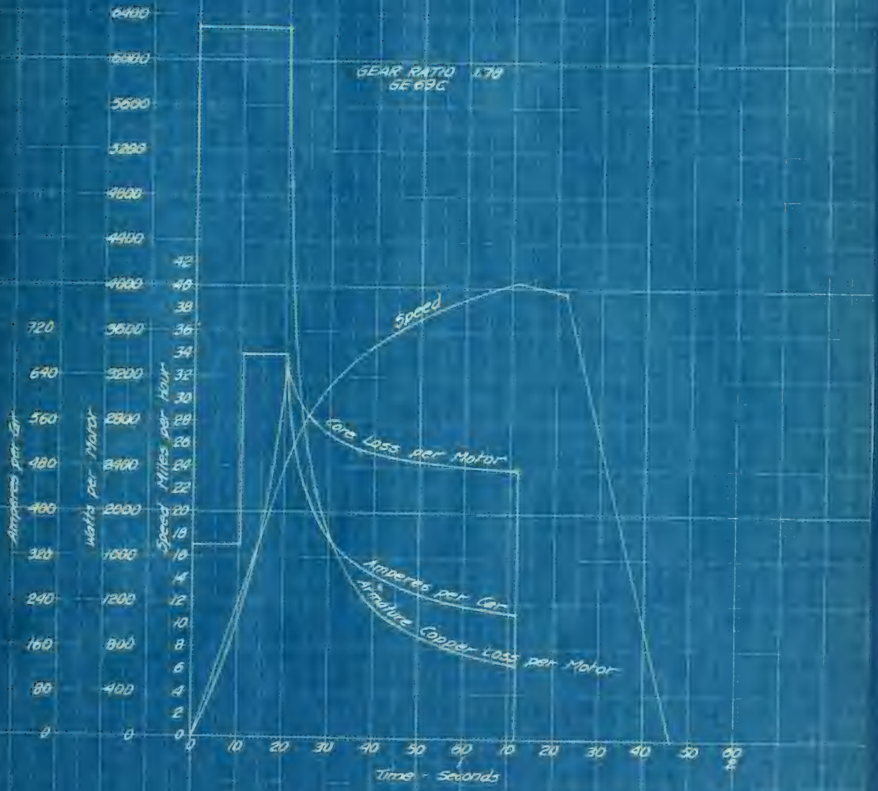
FIGURE No. 22



TYPICAL RUN - 0.815 MILES
2-GE69C Motors per Car 36" Wheels
Gear Ratio $\frac{48}{27}$ = 1.78
570 Volts

T.W.S.

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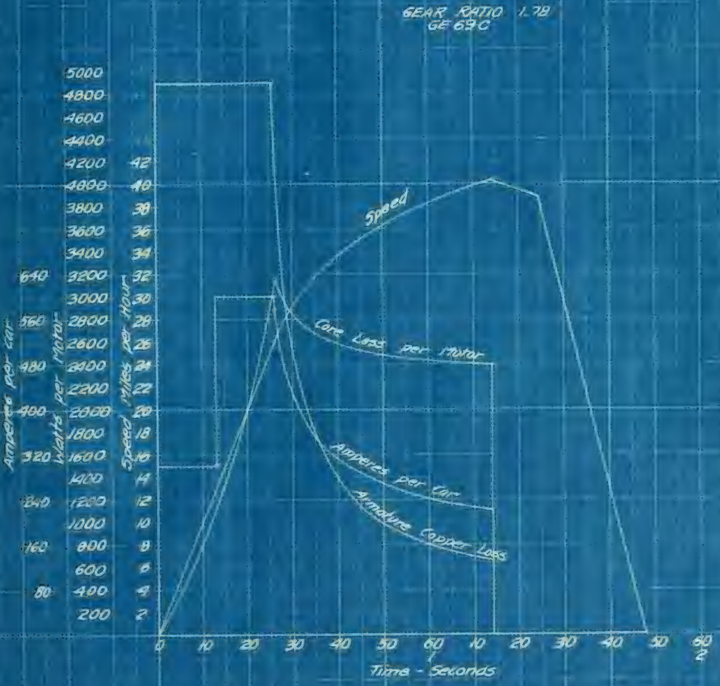
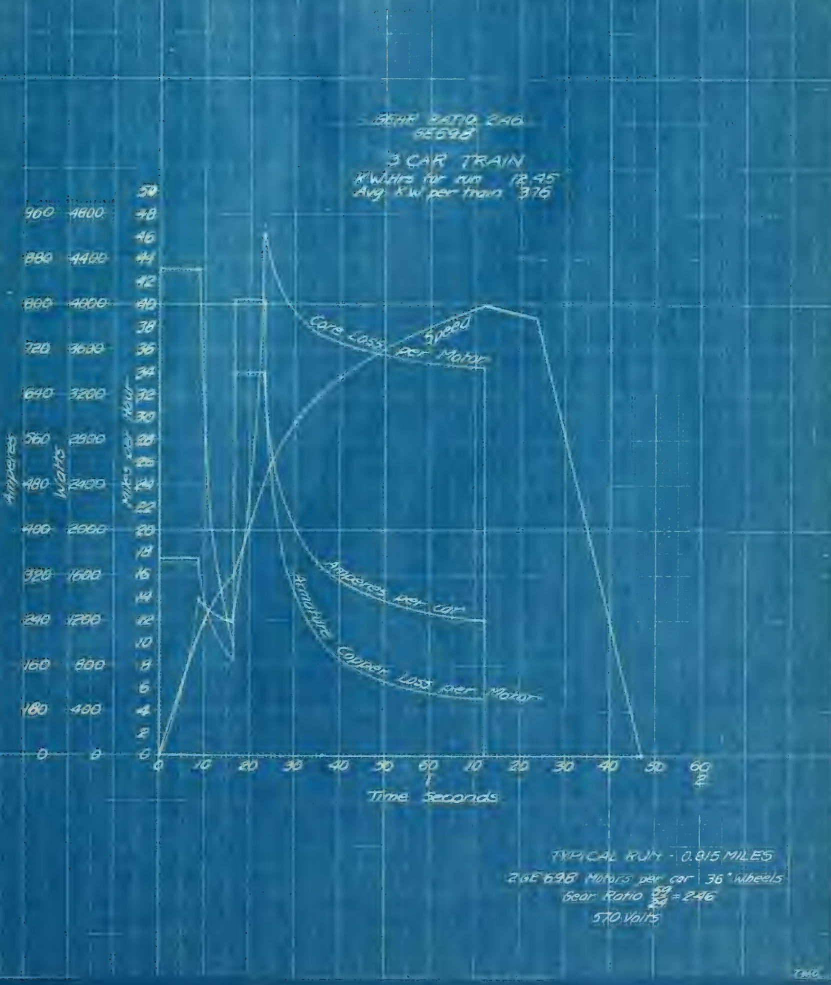
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 23



TYPICAL RUN 0.815 MILES
2 GE69C Motors per car 36" Wheels
Gear Ratio $\frac{48}{27}$ = 1.78
570 Volts

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 24



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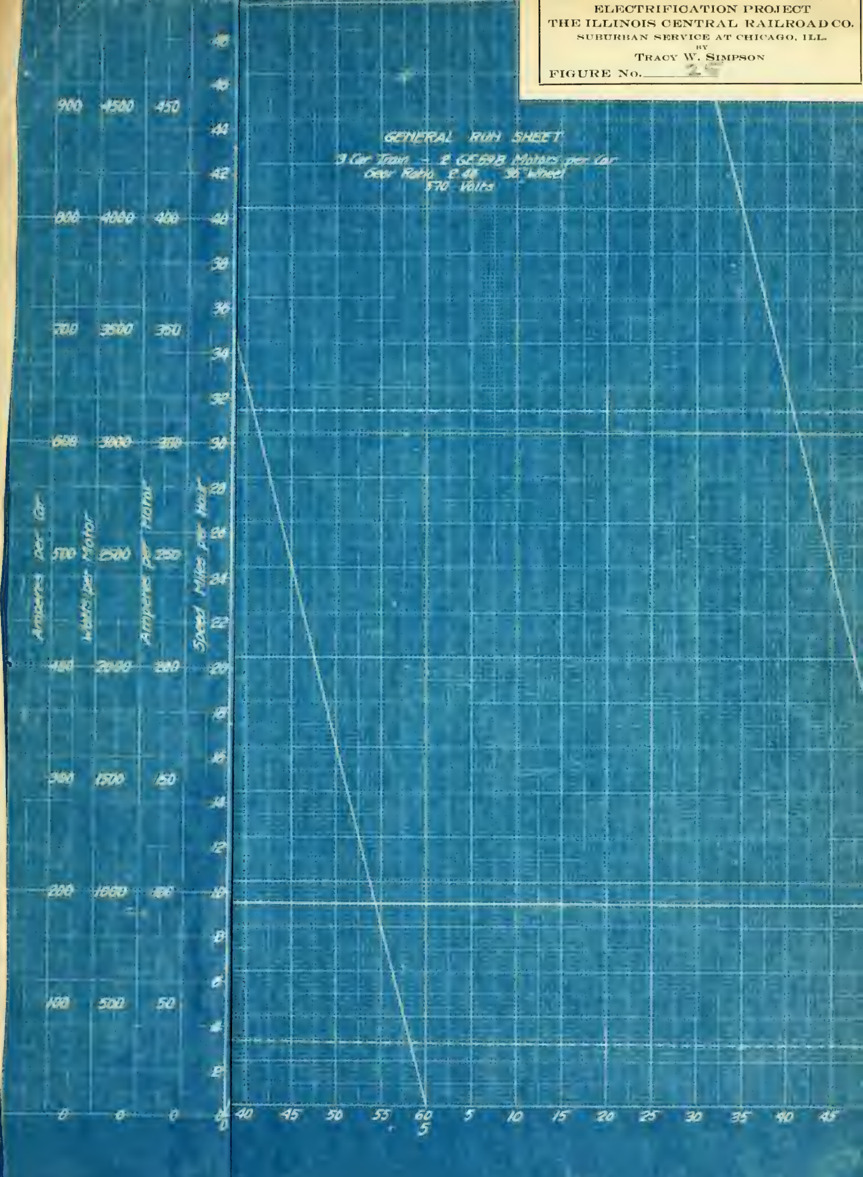
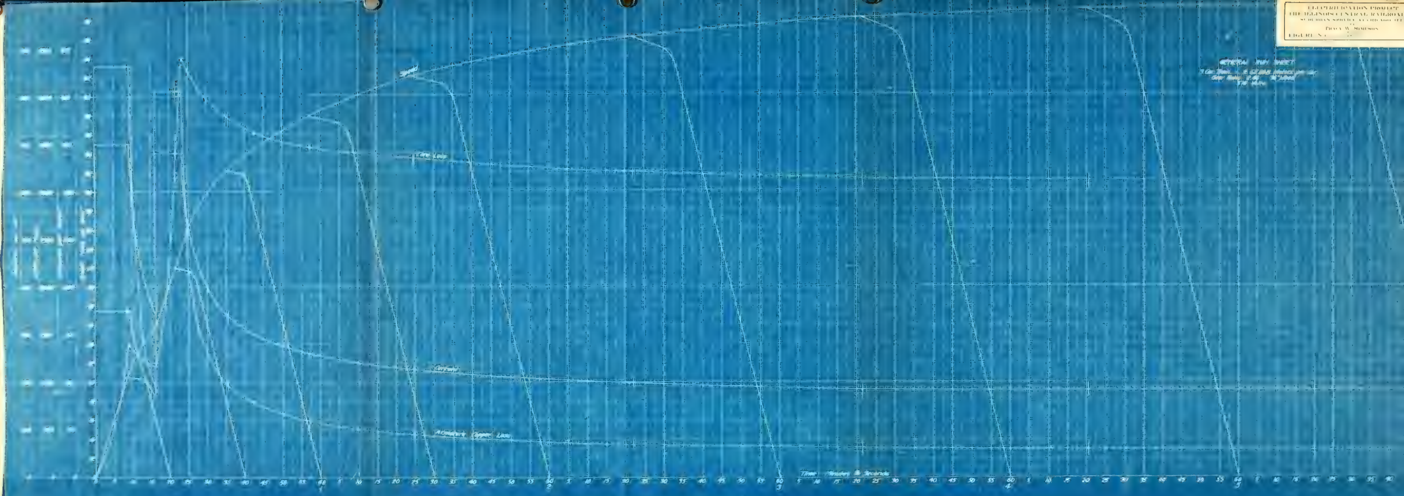
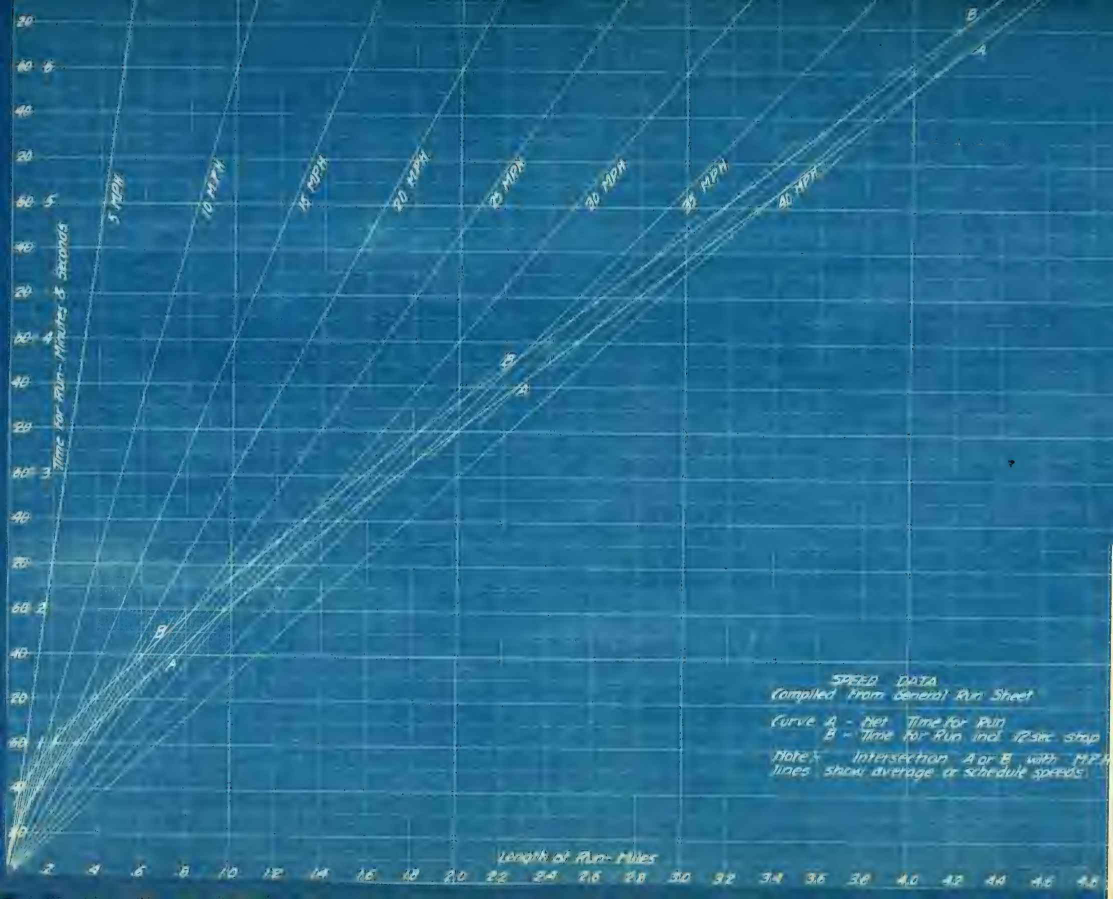
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 25



ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
PERCY W. SIMPSON
FIGURE No.





SPEED DATA
Compiled from General Run Sheet

Curve A - Net Time for Run
B - Time for Run incl. 12 sec. stop

Note:- Intersection A or B with M.P.H. lines show average or schedule speeds.

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SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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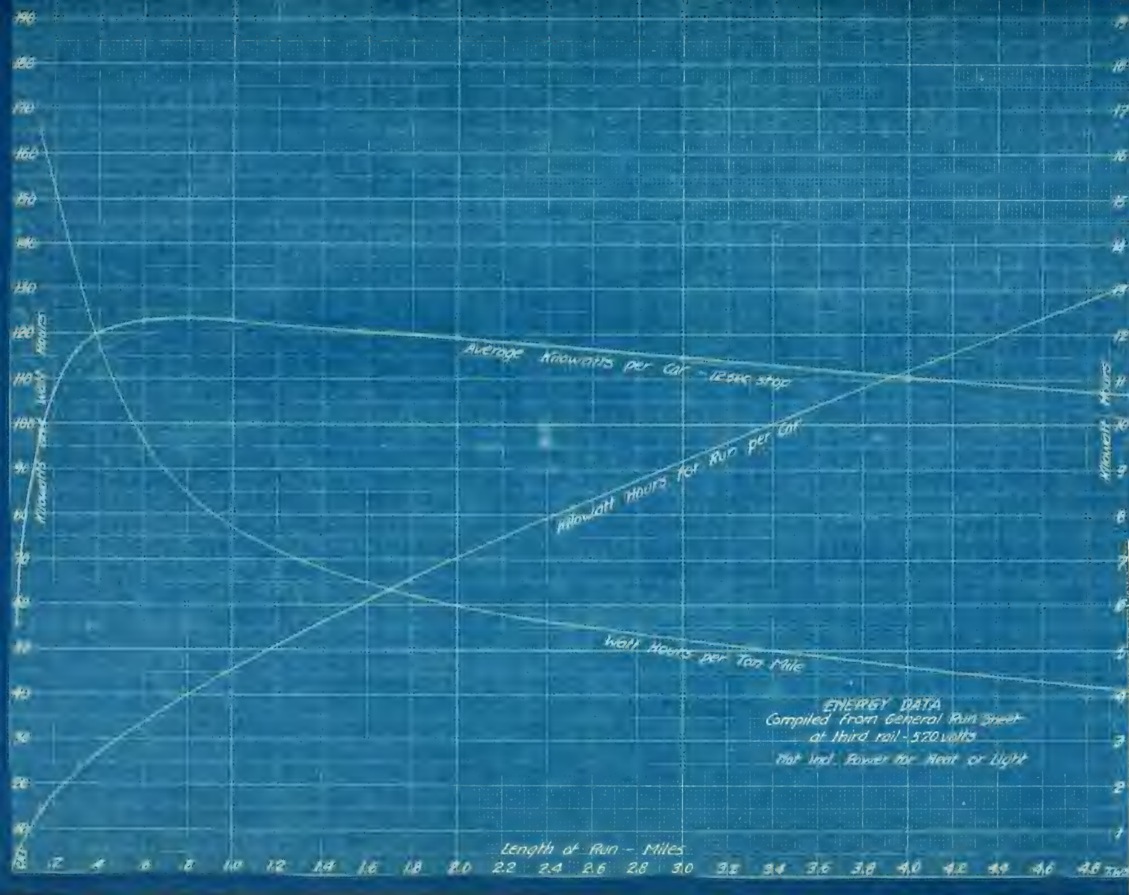
FIGURE No. 16



ELECTRIFICATION PROJECT
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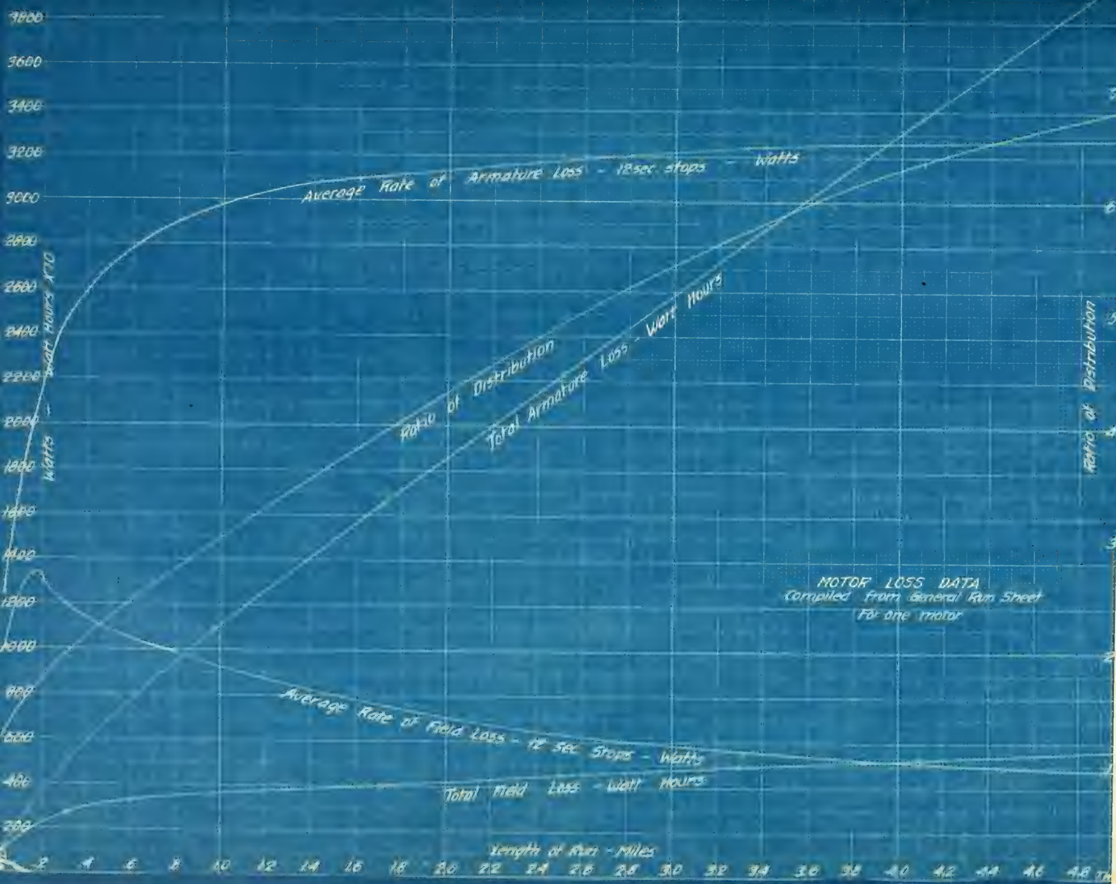
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 17

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 31



ELECTRIFICATION PROJECT
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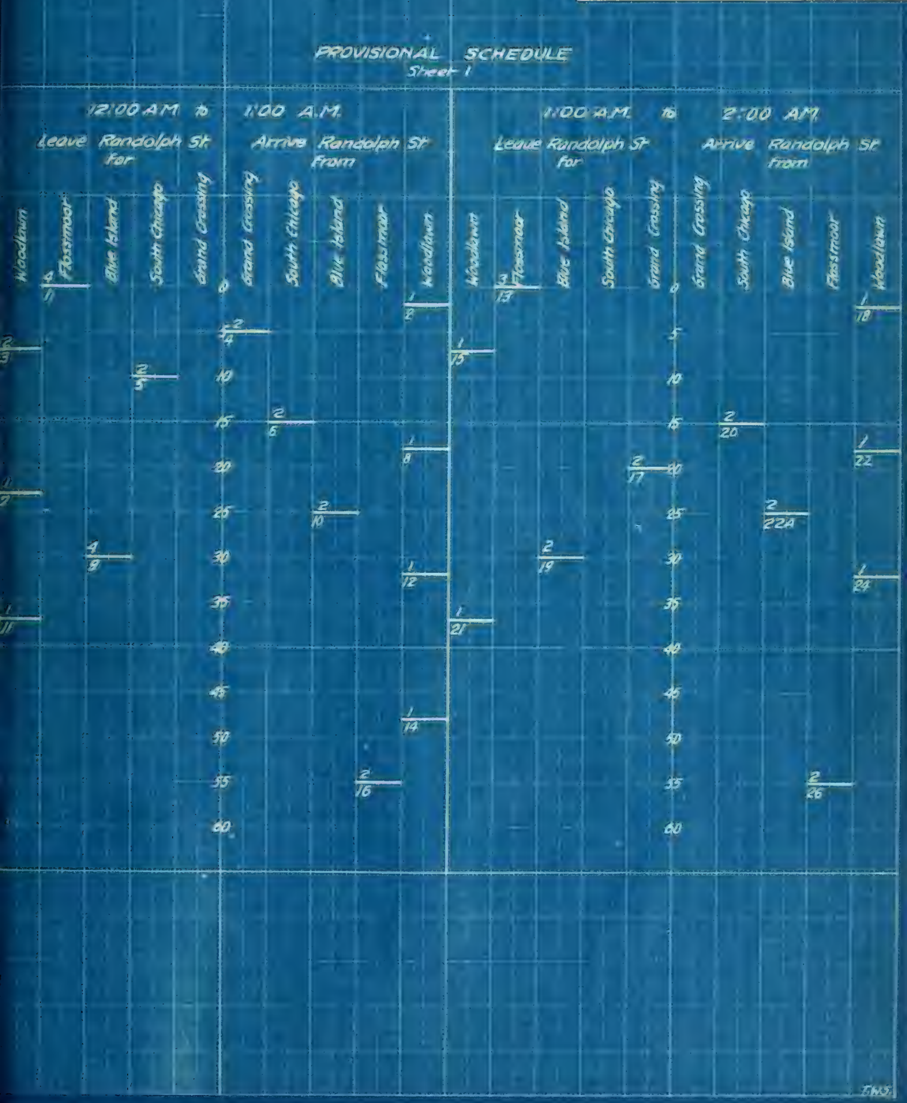
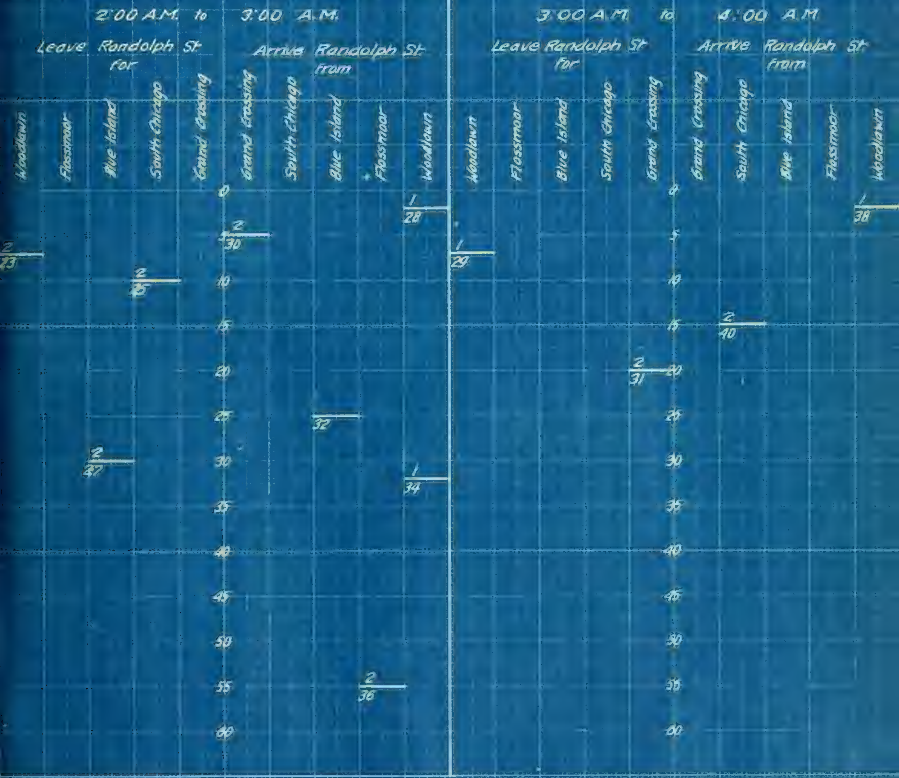
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 29



ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 30

PROVISIONAL SCHEDULE
Sheet 2



ELECTRIFICATION PROJECT
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SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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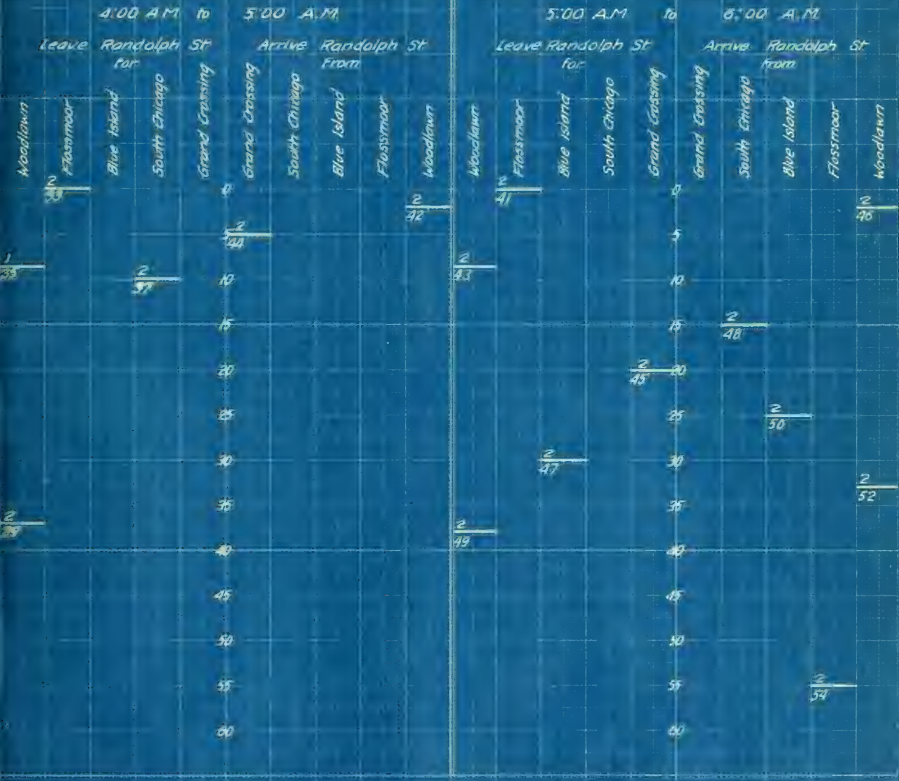
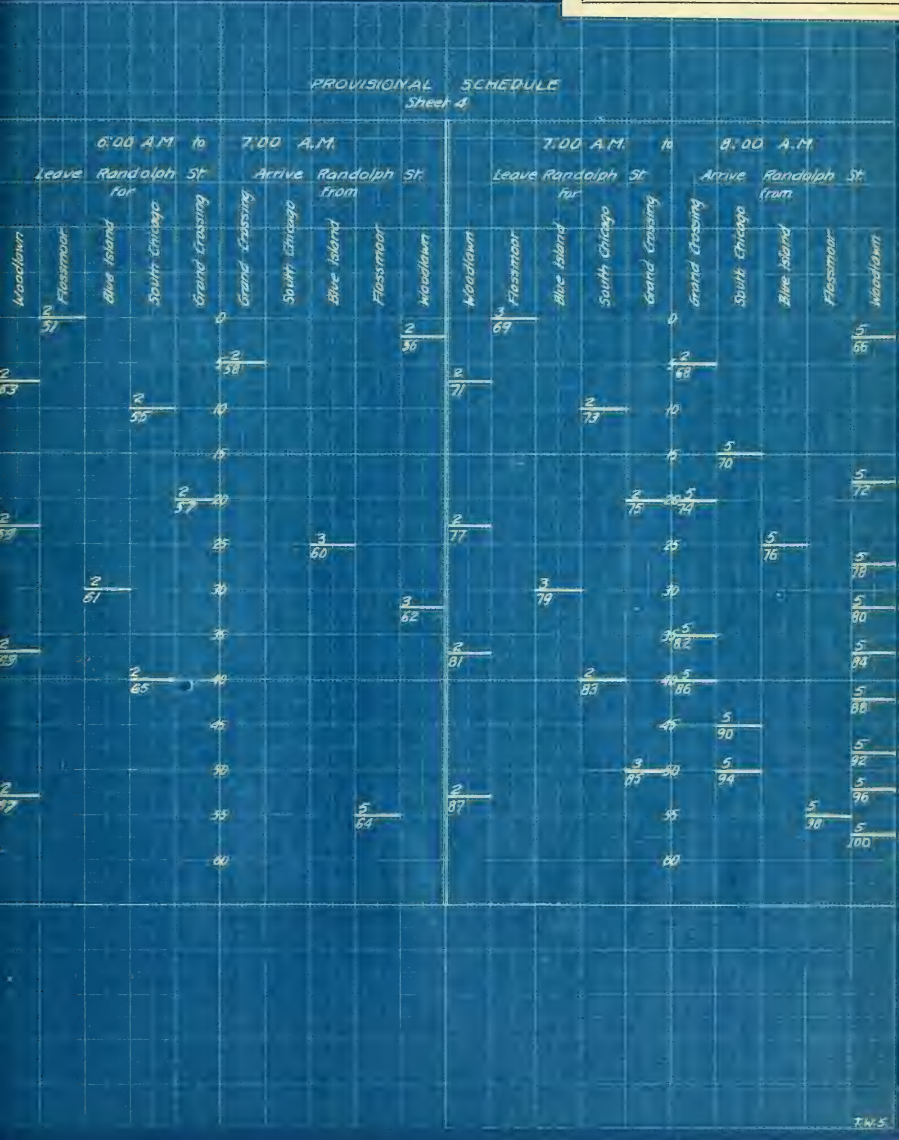
FIGURE No. 31

PROVISIONAL SCHEDULE
Sheet 3



T.W.S.

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No.



ELECTRIFICATION PROJECT
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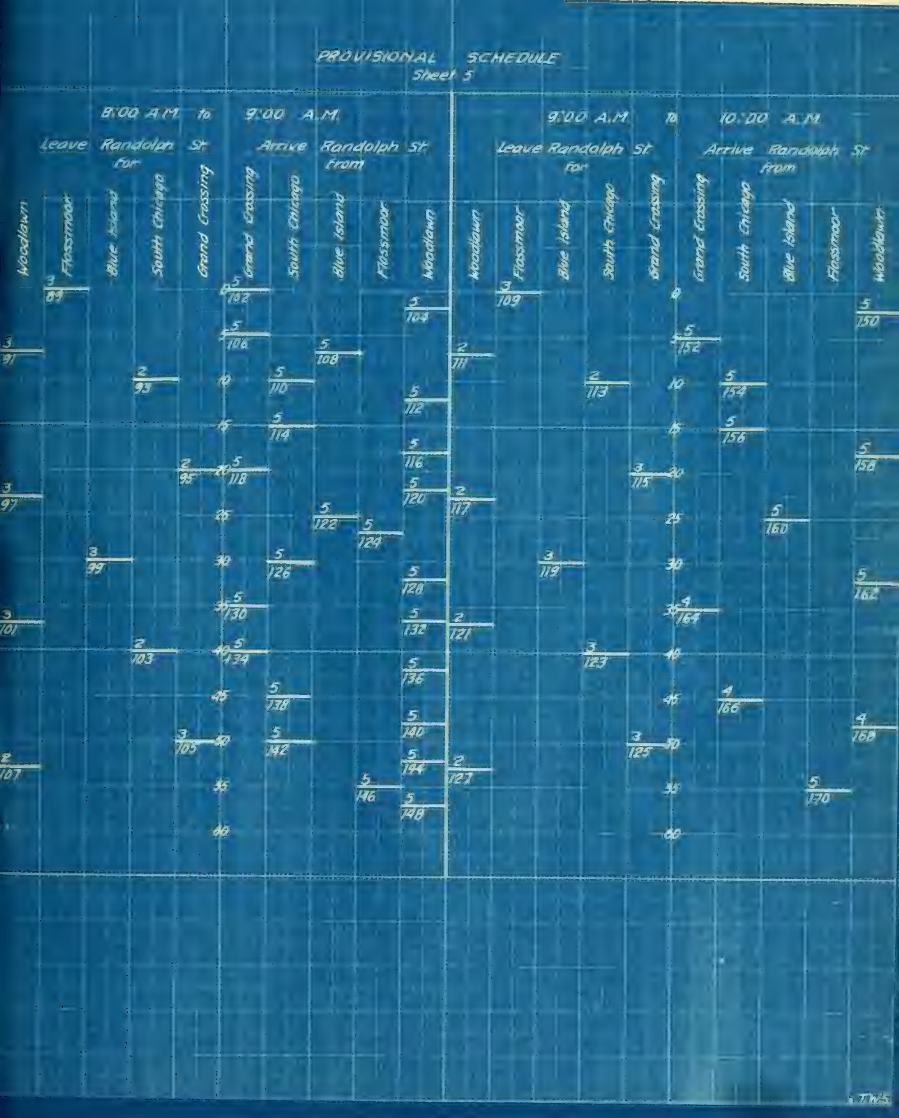
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No.



ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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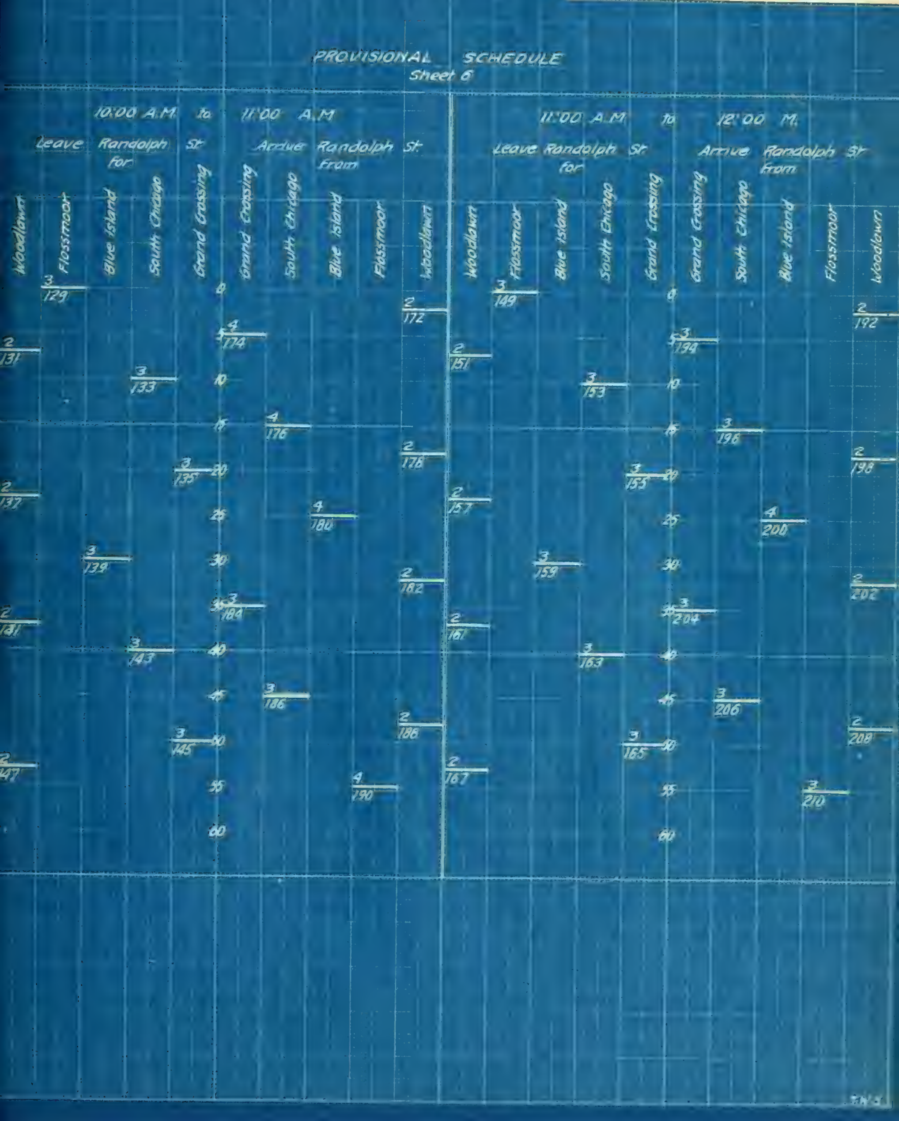
FIGURE No. 34



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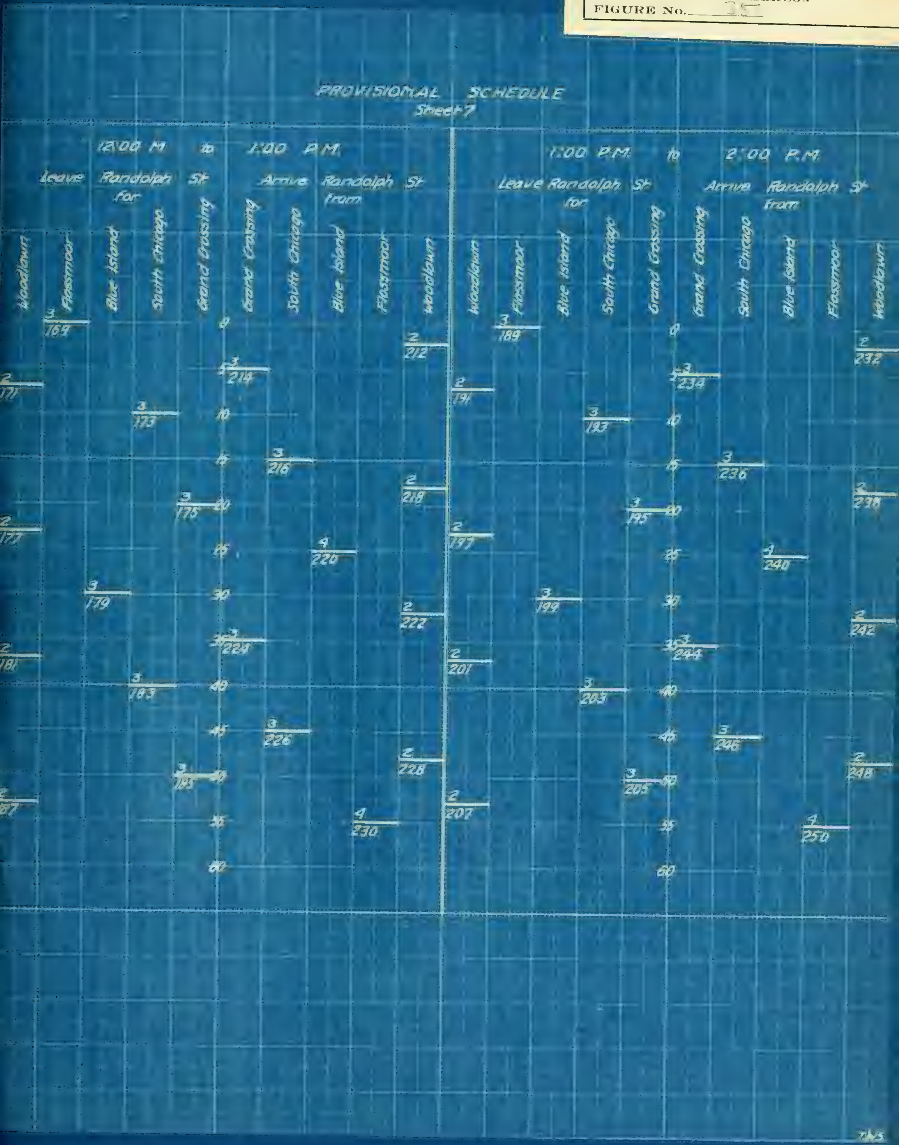
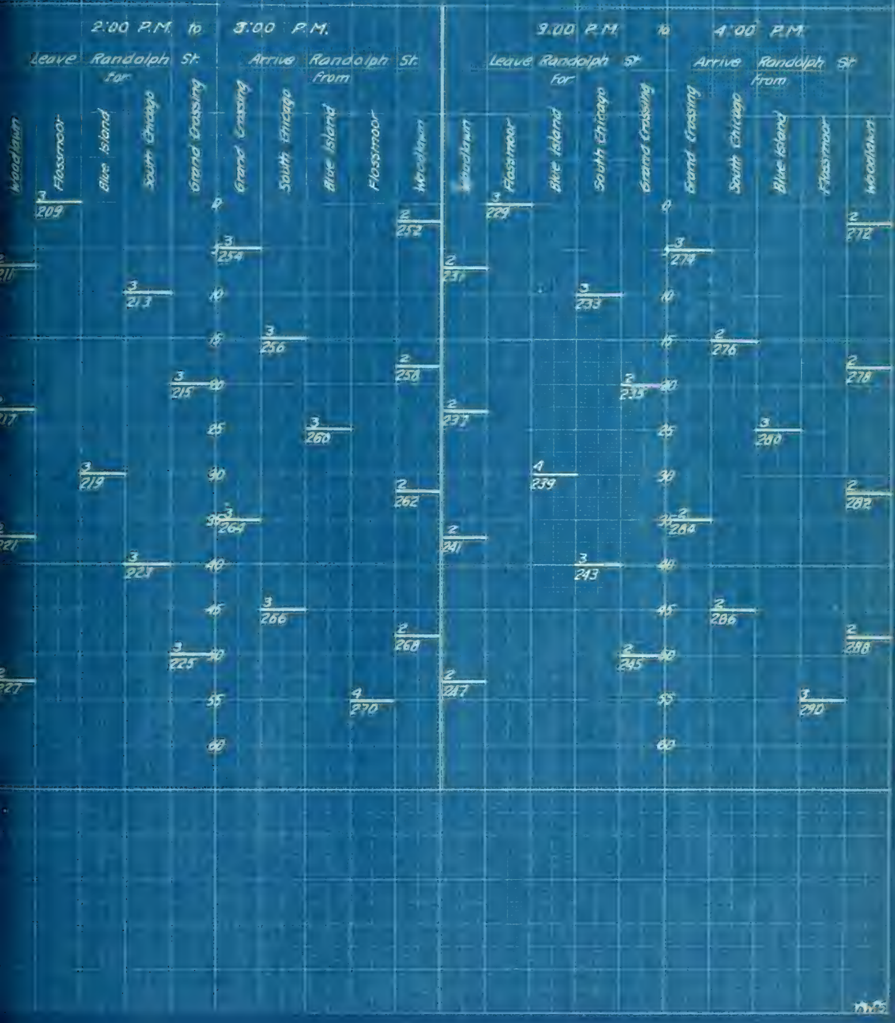
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 35



ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. [illegible]

PROVISIONAL SCHEDULE
Sheet 8



ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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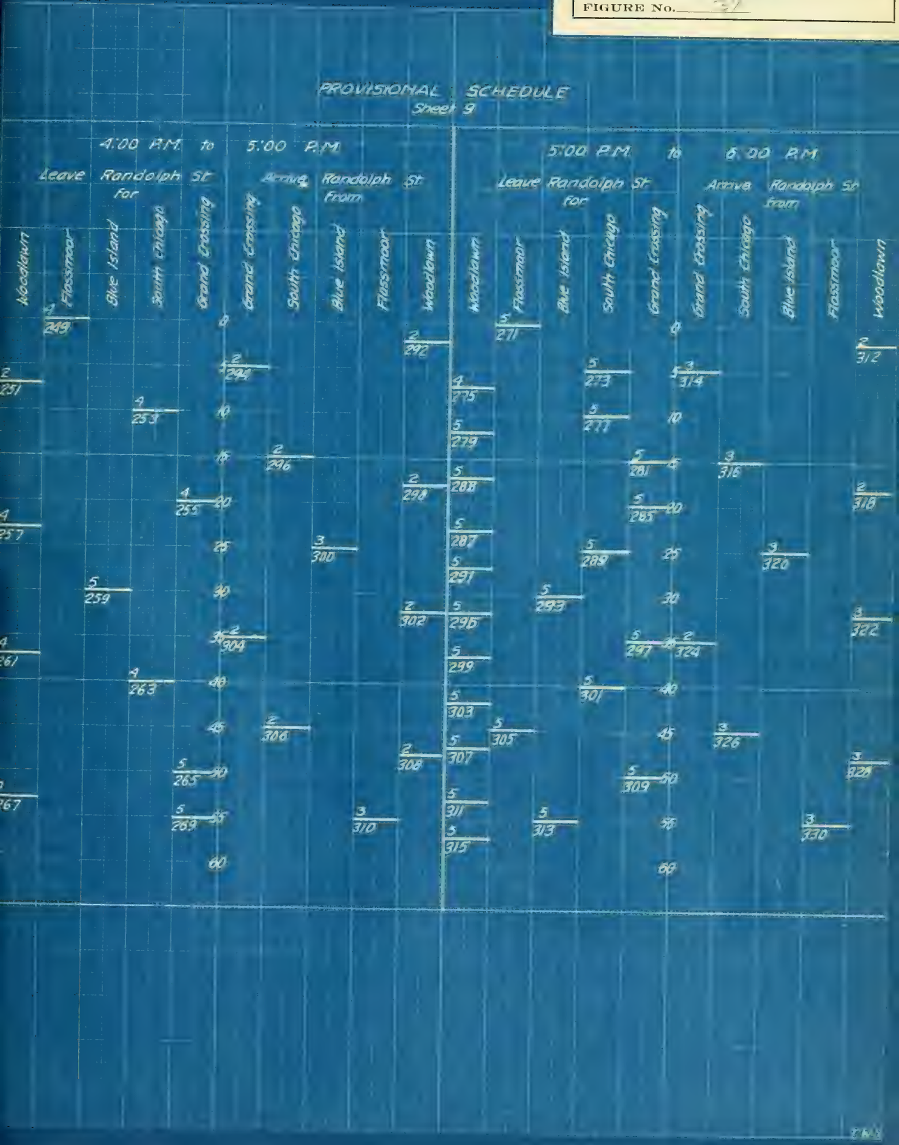
FIGURE No. 37



ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD C
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 32

PROVISIONAL SCHEDULE
Sheet 10

6:00 P.M. to 7:00 P.M.

Leave Randolph St for					Arrive Randolph St from				
Flossmoor	Blue Island	South Chicago	Grand Crossing		Grand Crossing	South Chicago	Blue Island	Flossmoor	Woodlawn
5 317				0					
									3 332
		5 321		5	3 334				
		5 325		10					
			5 329	15		3 336			
									5 338
			5 333	20					
		5 337		25			3 340		
	5 341			30					
									5 342
			5 345	35	3				
		5 349		40					
				45		3 344			
									5 346
			5 351	50					
				55				3 348	
				60					

7:00 P.M. to 8:00 P.M.

Leave Randolph St for						Arrive Randolph St from				
Woodlawn	Flossmoor	Blue Island	South Chicago	Grand Crossing		Grand Crossing	South Chicago	Blue Island	Flossmoor	Woodlawn
	5 355				0					
										2 350
					5	3 352				
5 357										
			5 359		10					
					15		3 354			
										4 356
				4 361	20					
3 363										
					25			3 358		
		4 365			30					
										3 360
					35	4 362				
2 367										
			4 367A		40					
					45		4 362A			
										3 364
					50					
2 369										
					55				3 366	
					60					

TWS

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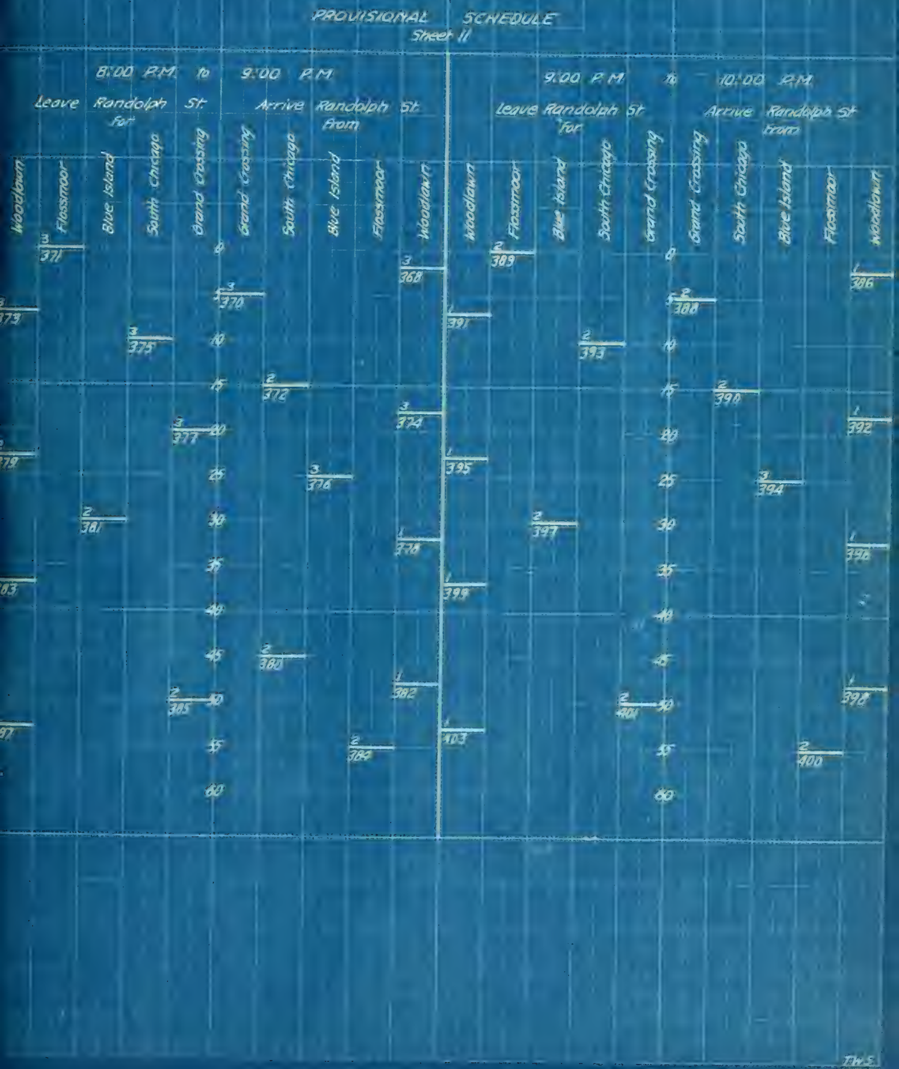
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. [illegible]



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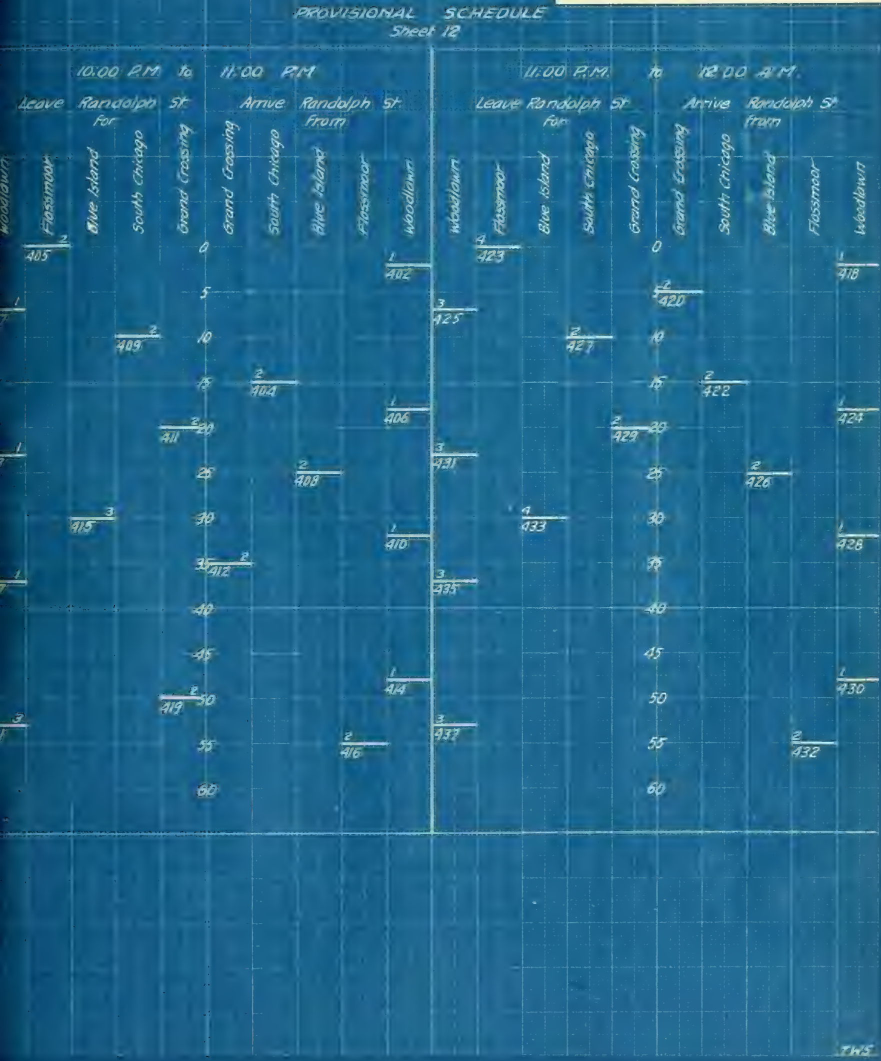
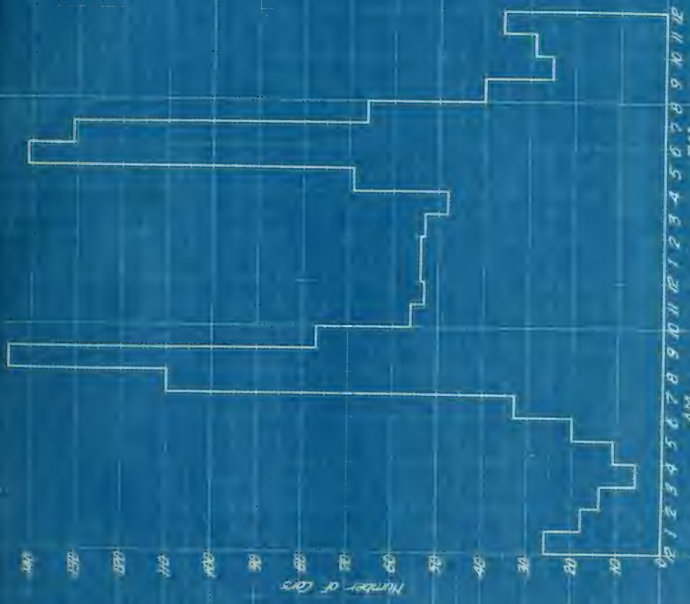
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 40



PROVISIONAL SCHEDULE
Sheet 12

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 41

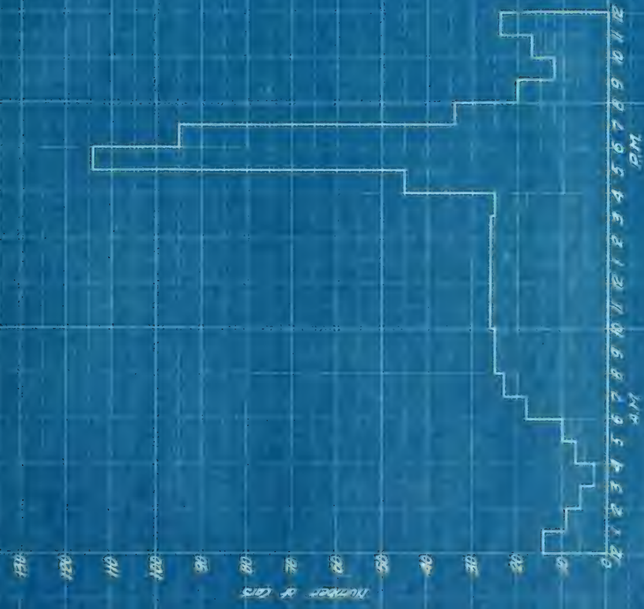


PROVISIONAL SCHEDULE

Diagram showing cars leaving and arriving at Randolph St. during each hour for typical week day service

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON

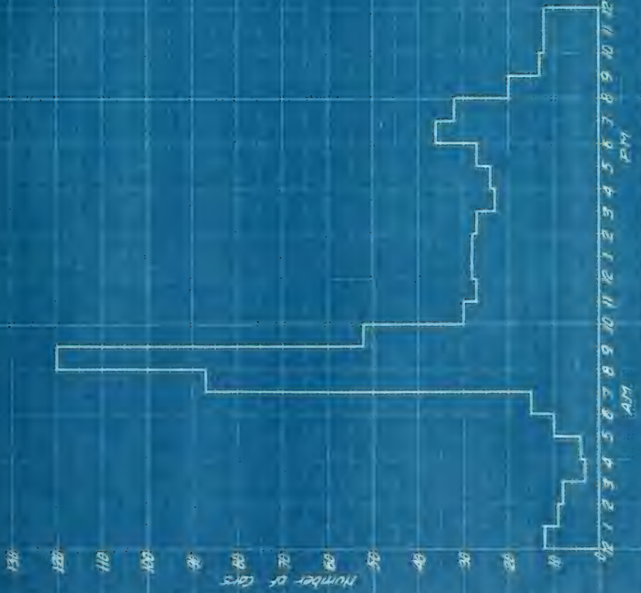
FIGURE No. 42



PROVISIONAL SCHEDULE

Diagram showing cars leaving Randolph St during each hour for typical week day service

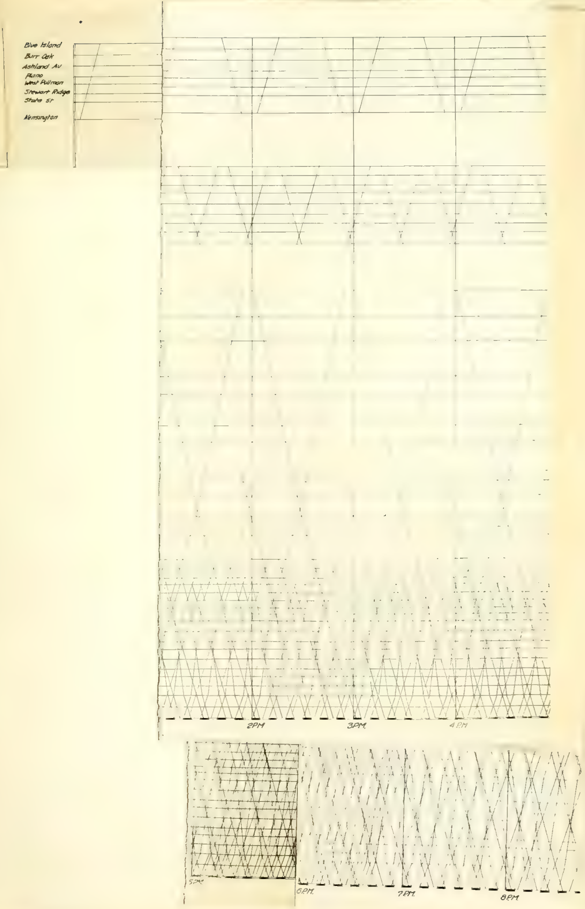
ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 43

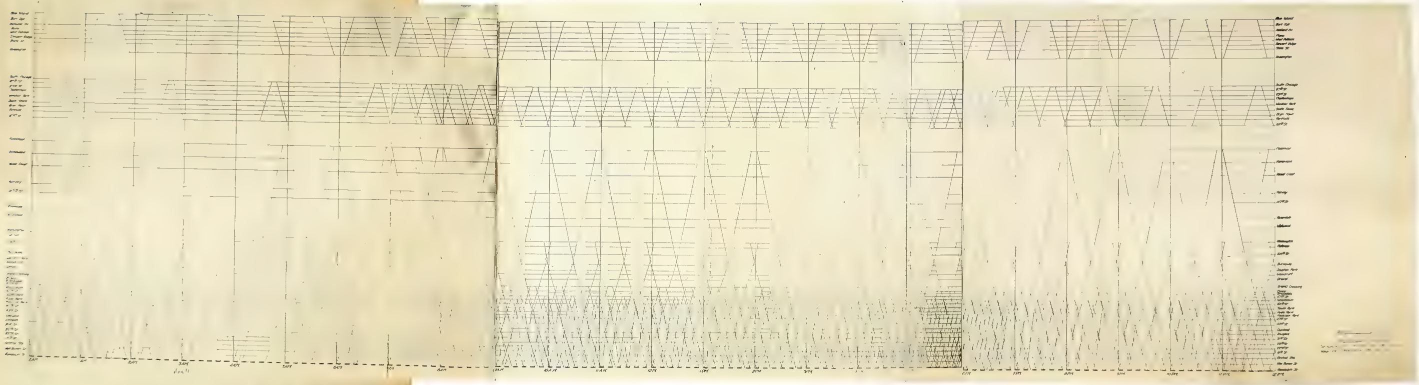


PROVISIONAL SCHEDULE

Diagram showing cars arriving at Randolph St. during each hour for typical week day service

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. ______




Blue Island
Burr Oak
Ashland Av
West Pullman
Stewart Ridge
State St
Kensington
South Chicago
87th St
83rd St
Cheltenham
Windsor Park
South Shore
Bryn Mawr
Parkside
67th St
Flossmoor
Homewood
Hazel Crest
Harvey
147th St
Riverdale
Pullman
111th St
Burnside
Dauphin Park
Woodruff
Grand Crossing
67th St
Woodlawn
63rd St
South Park
Hyde Park
47th St
43rd St
Oakwood
Douglas
31st St
27th St
22nd St
18th St
Central Sta
Van Buren St
Randolph St
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
6 PM
7 PM
8 PM
9 PM
10 PM
11 PM
12 PM

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 45

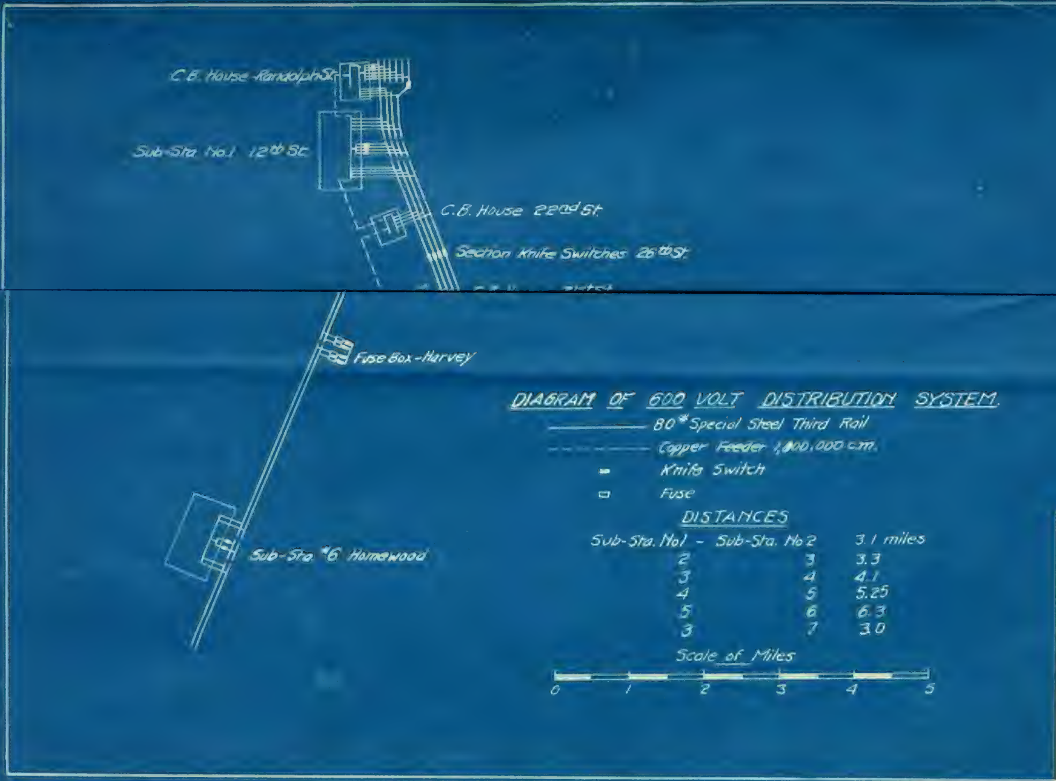
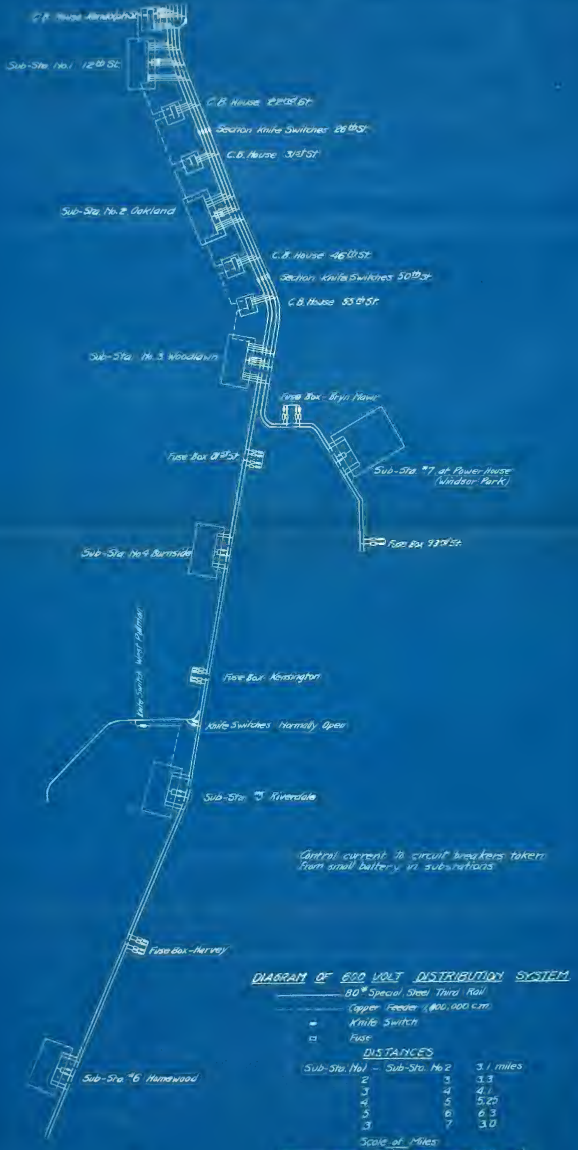


DIAGRAM OF 600 VOLT DISTRIBUTION SYSTEM.

DISTANCES

Sub-Sta. No1 -	Sub-Sta. No 2	3.1 miles
2	3	3.3
3	4	4.1
4	5	5.25
5	6	6.3
3	7	3.0



Control current to circuit breakers taken from small battery in substations.

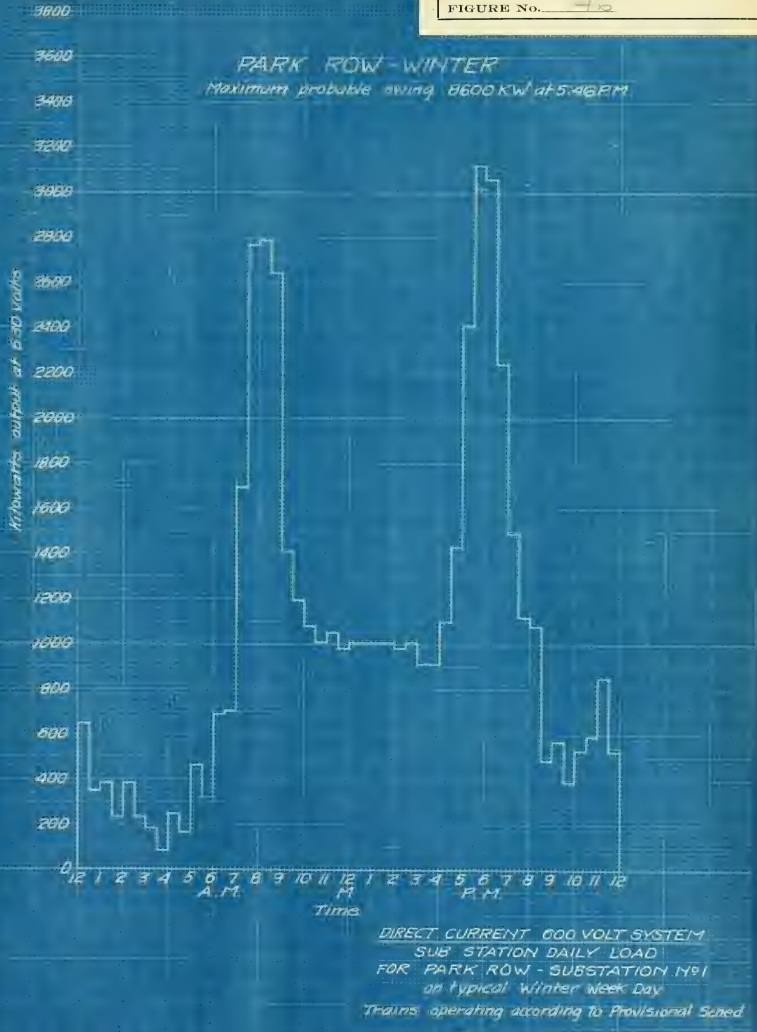
DIAGRAM OF 600 VOLT DISTRIBUTION SYSTEM.

DISTANCES

Sub-Sta. No1	- Sub-Sta. No2	3.1 miles
2	3	3.3
3	4	4.1
4	5	5.25
5	6	6.3
3	7	3.0

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 45

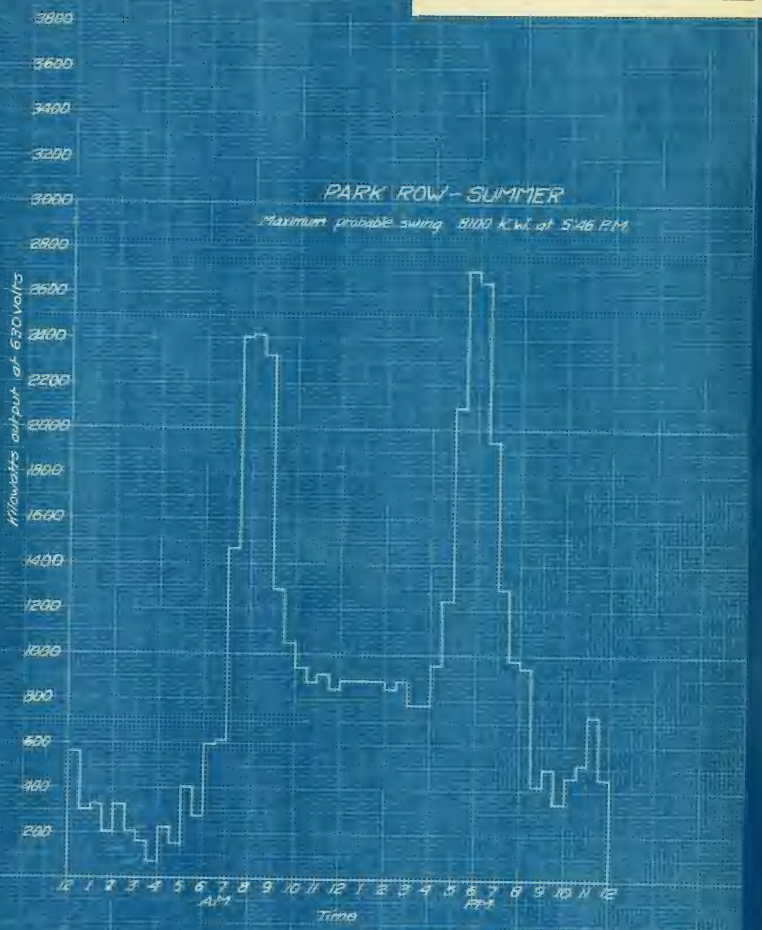
ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 42


PARK ROW - WINTER
Maximum probable swing 8600 KW at 5.46 P.M.

DIRECT CURRENT 600 VOLT SYSTEM
SUB STATION DAILY LOAD
FOR PARK ROW - SUBSTATION No. 1
on typical Winter Week Day
Trains operating according to Provisional Sched

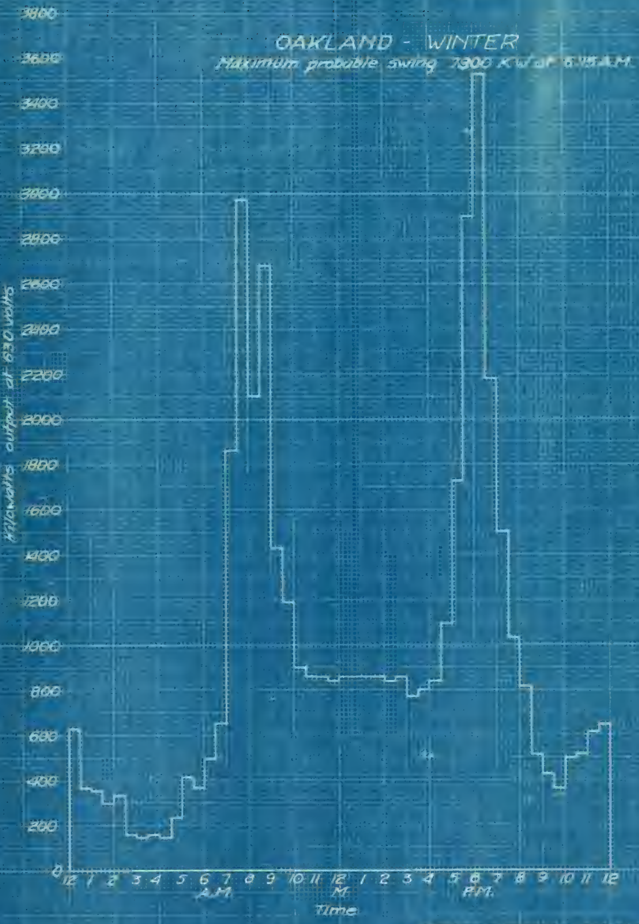
T.W.S.

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 47



DIRECT CURRENT 600 VOLT SYSTEM
SUB STATION DAILY LOAD
FOR PARK ROW - SUBSTATION NO1.
for typical Summer Week Day
Trains operating according to Provisional Schedule

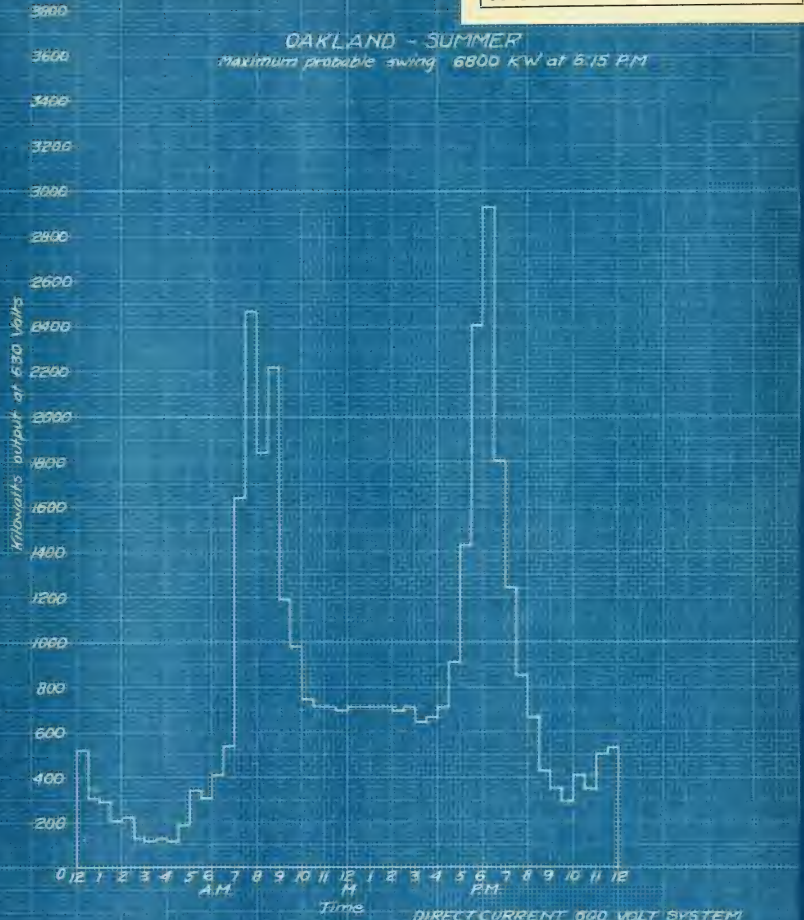
ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 46



DIRECT CURRENT 600 VOLT SYSTEM
SUB STATION DAILY LOAD
FOR OAKLAND SUB STATION Nº2
on typical Winter Week Day
Trains operating according to Provisional Schedule

TWO

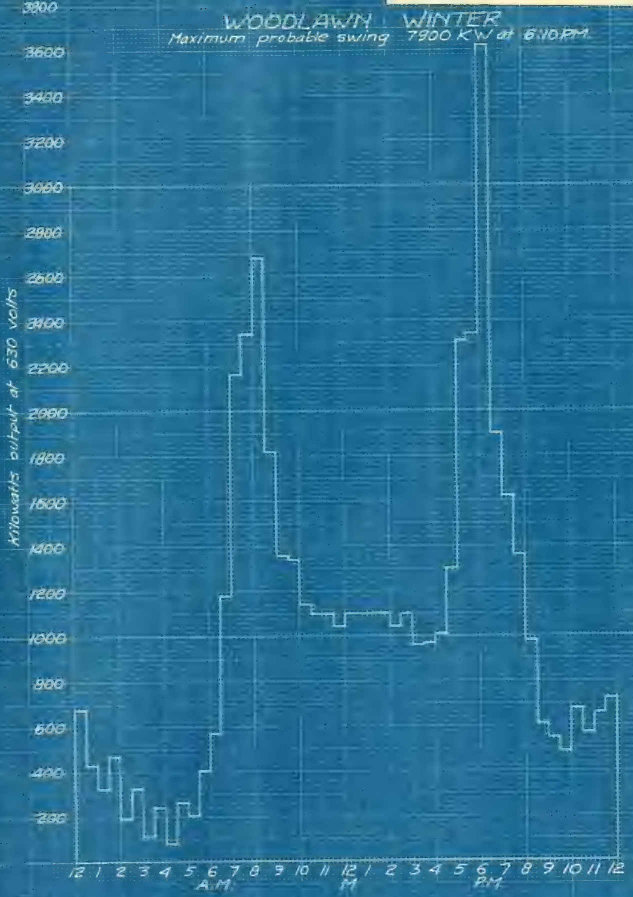
ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 49



DIRECT CURRENT 600 VOLT SYSTEM
SUB STATION DAILY LOAD
FOR OAKLAND SUB STATION Nº 2
on typical Summer Week Day
Trains operating according to Provisional Schedule

T.W.S.

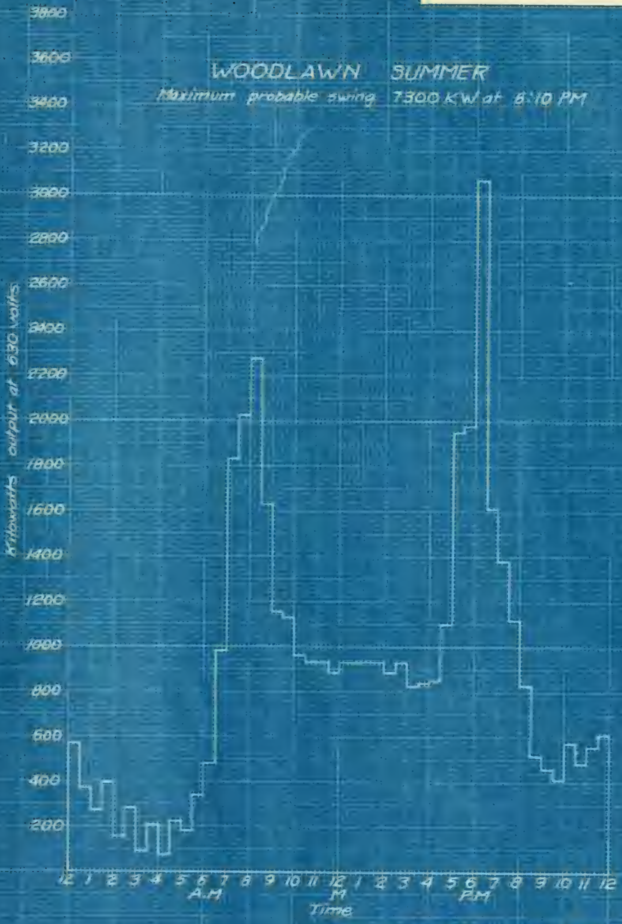
ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 50



DIRECT CURRENT 600VOLT SYSTEM
SUB STATION DAILY LOAD
FOR WOODLAWN SUB STATION Nº 3
on typical Winter week day
Trains operating according to Provisional Schedule

TWS

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 51

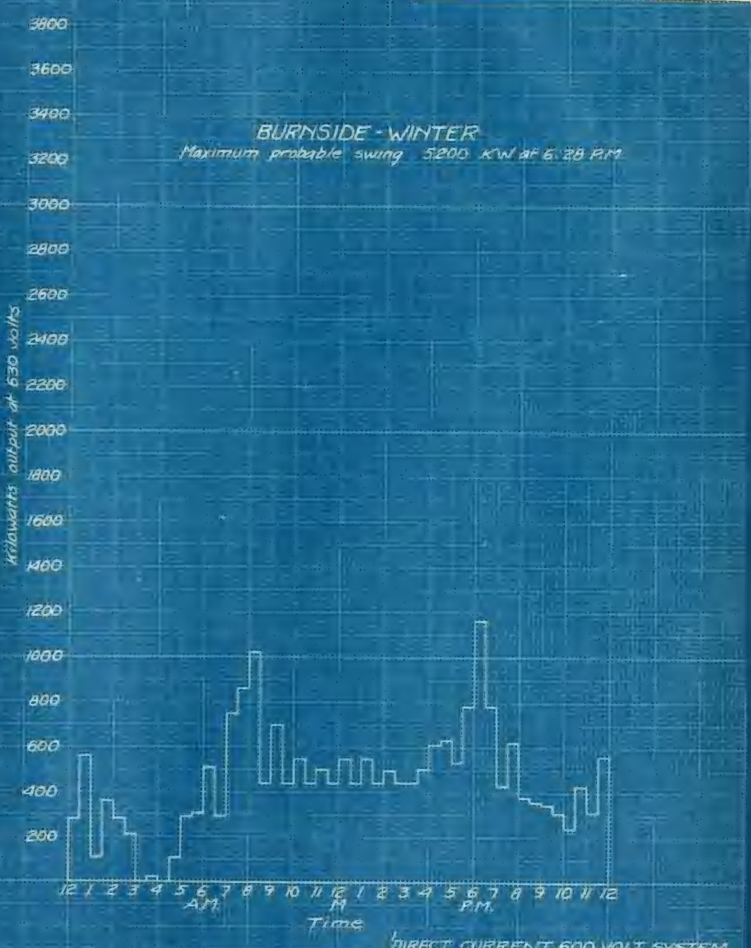


DIRECT CURRENT 600 VOLT SYSTEM
SUB STATION DAILY LOAD
FOR WOODLAWN SUB STATION Nº 3
on typical Summer week day

Trains operating according to Provisional Sched.

TWS

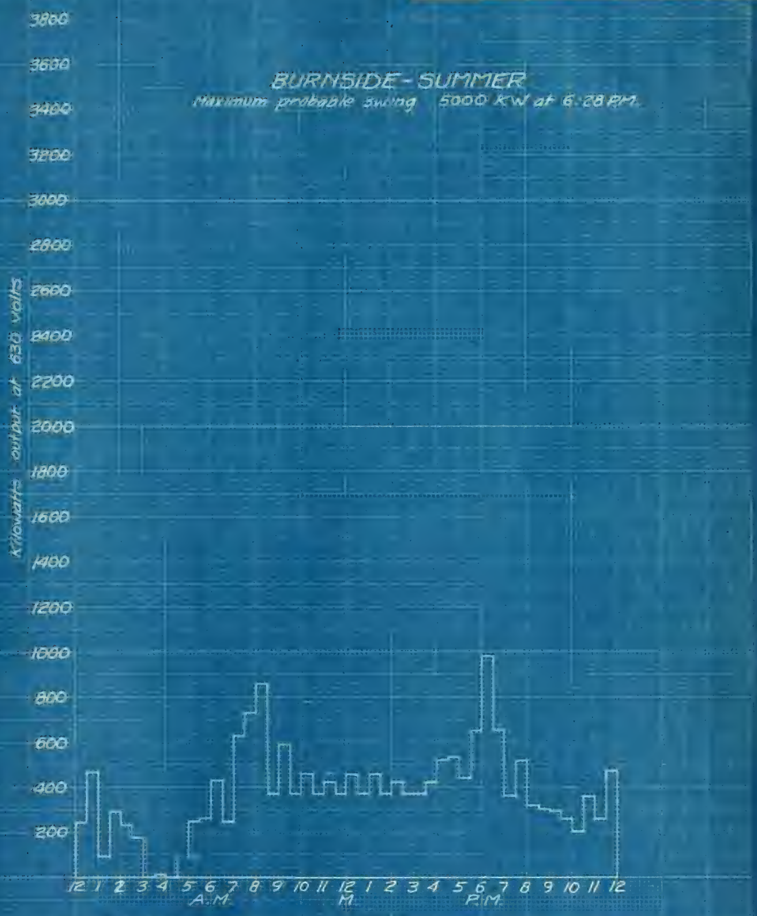
ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 52



BURNSIDE - WINTER
Maximum probable swing 5200 KW at 6.28 P.M.

DIRECT CURRENT 600 VOLT SYSTEM
SUB STATION DAILY LOAD
FOR BURNSIDE SUB STATION Nº4
on typical Winter week day
Trains operating according to Provisional Schedule

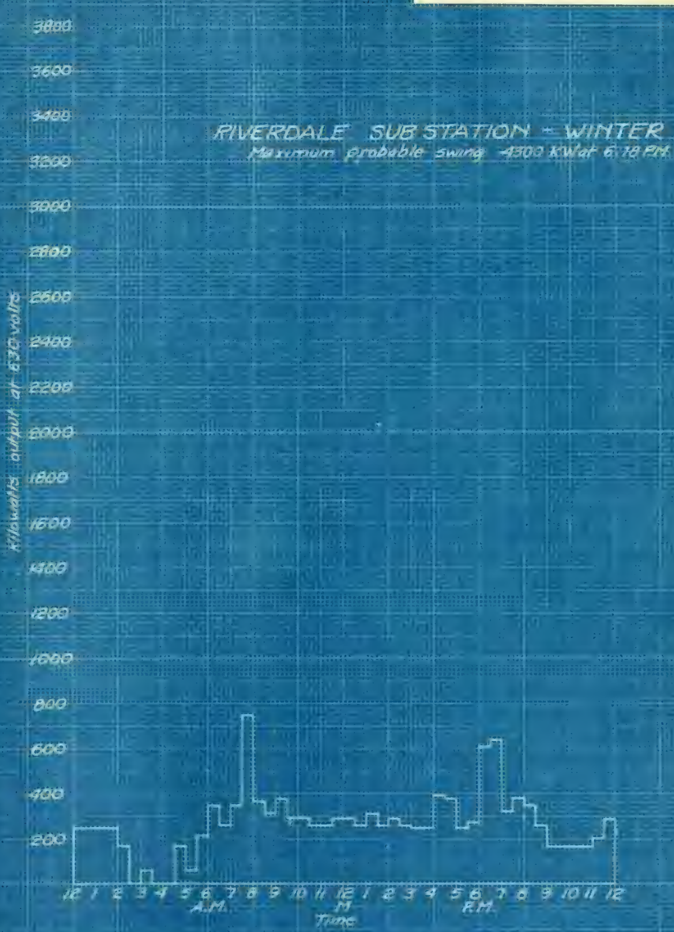
ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 53



DIRECT CURRENT 600 VOLT SYSTEM
SUB STATION DAILY LOAD
FOR BURNSIDE SUBSTATION Nº 4
on typical Summer week day
Trains operating according to Provisional Schedule

TWS

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 54

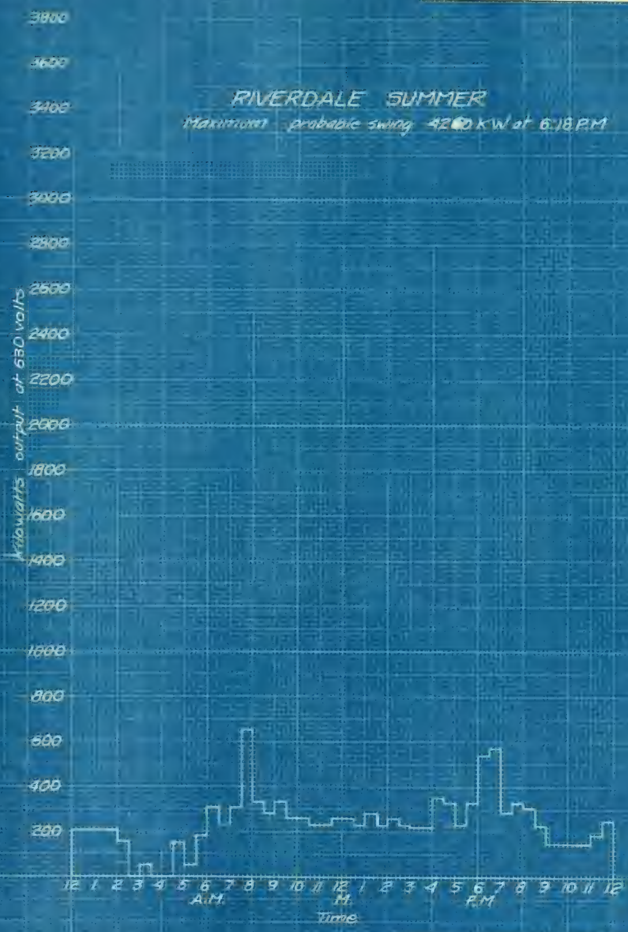

RIVERDALE SUB STATION - WINTER
Maximum probable swing 4300 KW at 6.18 P.M.

DIRECT CURRENT 600 VOLT SYSTEM
SUB STATION DAILY LOAD
FOR RIVERDALE SUB STATION Nº 5
on typical Winter week day

Trains operating according to Provisional Sched.

TWS

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 85



RIVERDALE SUMMER

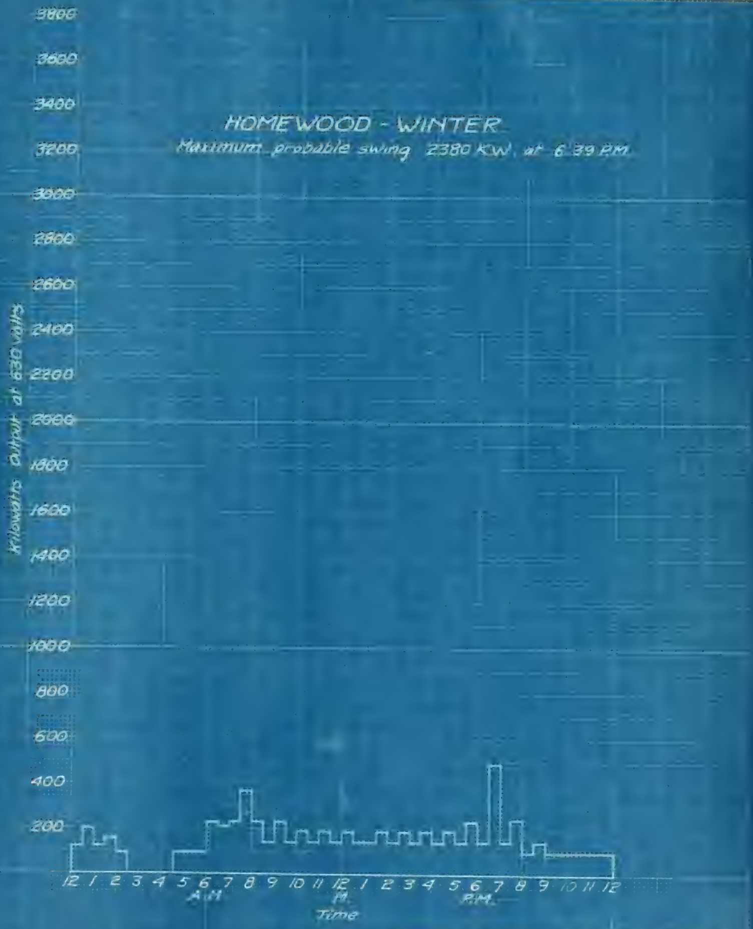
Maximum probable swing 420 KW at 6.18 P.M

DIRECT CURRENT 600 VOLT SYSTEM
SUB STATION DAILY LOAD
FOR RIVERDALE SUB STATION Nº 5
on typical Summer week day

Trains operating according to Provisional Schedule

TWS

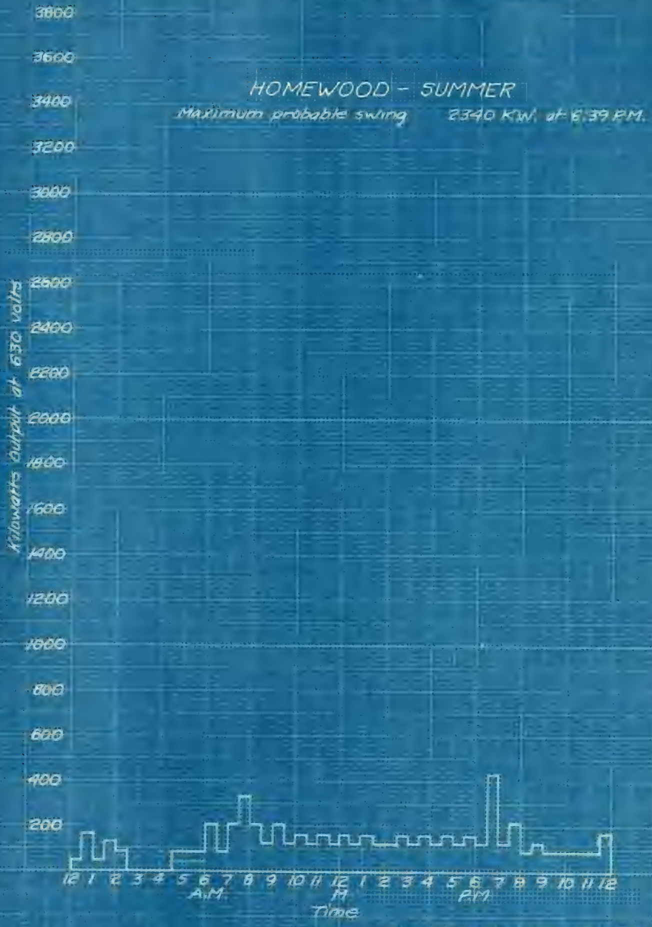
ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No.



DIRECT CURRENT 600 VOLT SYSTEM
SUB STATION DAILY LOAD
FOR HOMEWOOD SUB STATION Nº 6
on typical Winter week day

Trains operating according to Provisional Schedule

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 57

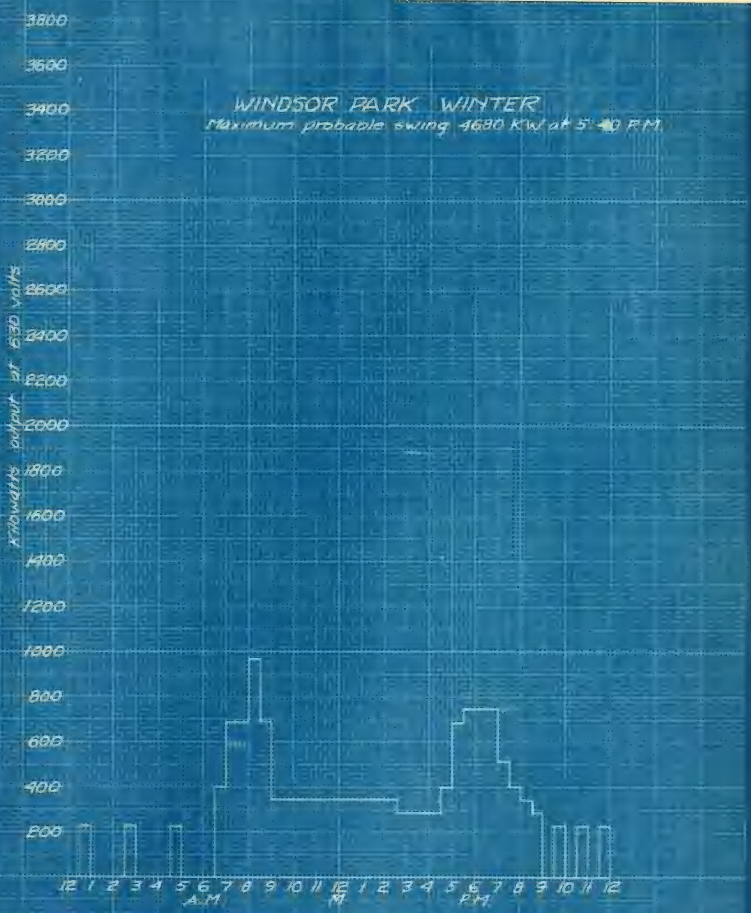

HOMEWOOD - SUMMER

Maximum probable swing 2340 K.W. at 6.39 P.M.

DIRECT CURRENT 600 VOLT SYSTEM
SUB STATION DAILY LOAD
FOR HOMEWOOD SUB STATION Nº 6
on typical Summer week day
Trains operating according to Provisional Schedule

TWS.

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 52



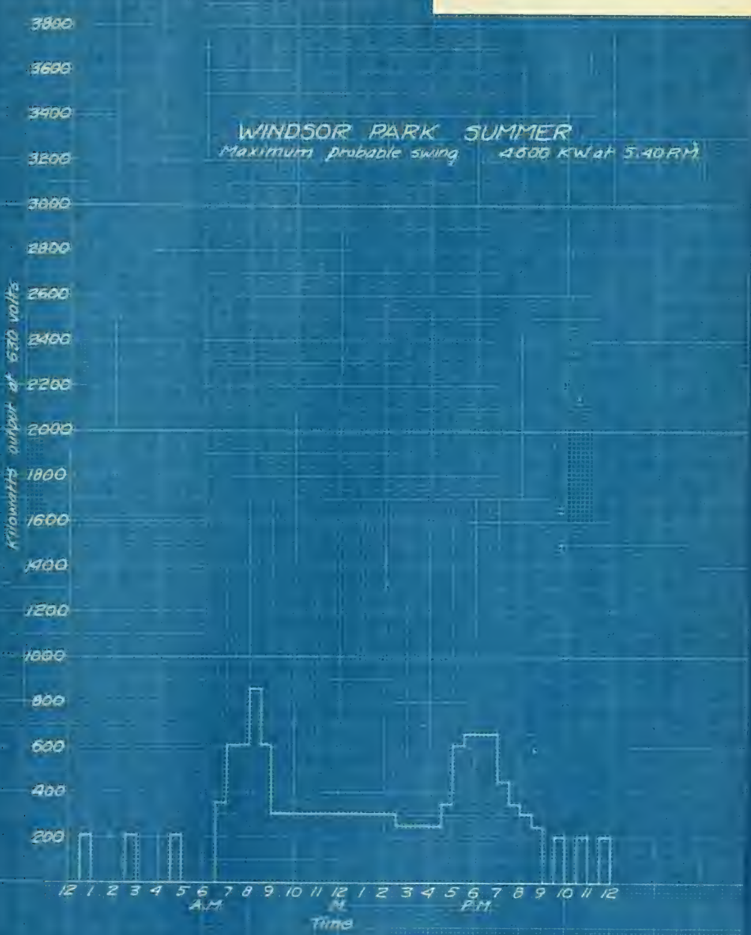
DIRECT CURRENT 600 VOLT SYSTEM
SUB STATION DAILY LOAD
FOR WINDSOR PARK SUB STATION No. 7
on typical Winter week day

Trains operating according to Provisional Schedule

TWS

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON

FIGURE No. 59

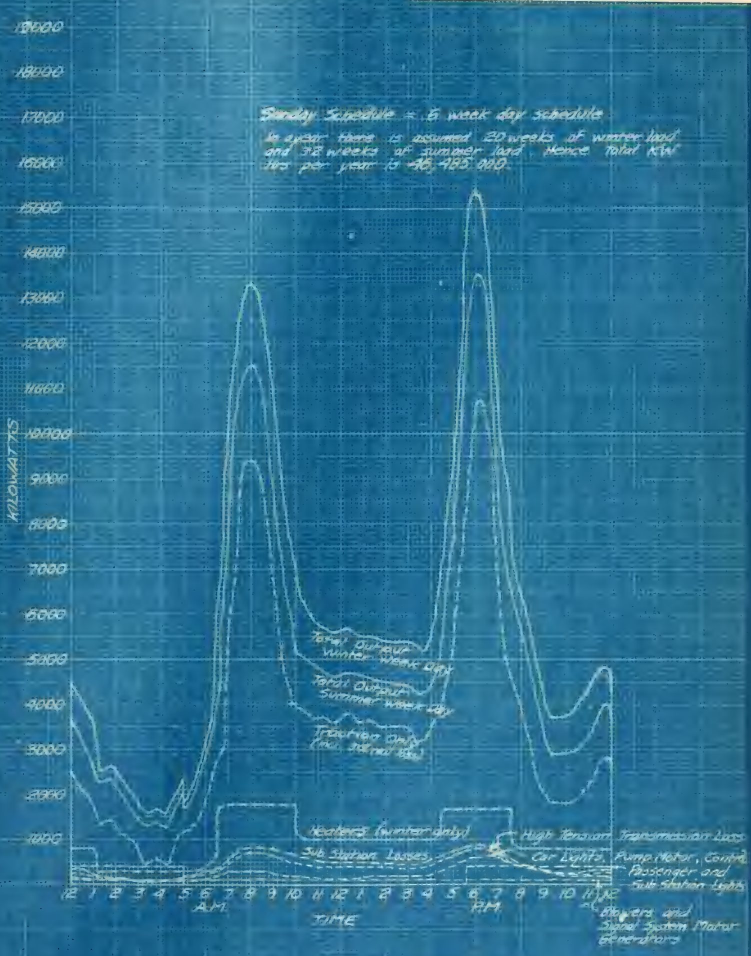


DIRECT CURRENT 600 VOLT SYSTEM
SUB STATION DAILY LOAD
FOR WINDSOR PARK SUBSTATION No. 7
for typical Summer week day

Trains operating according to Provisional Schedule.

TWS

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No.________



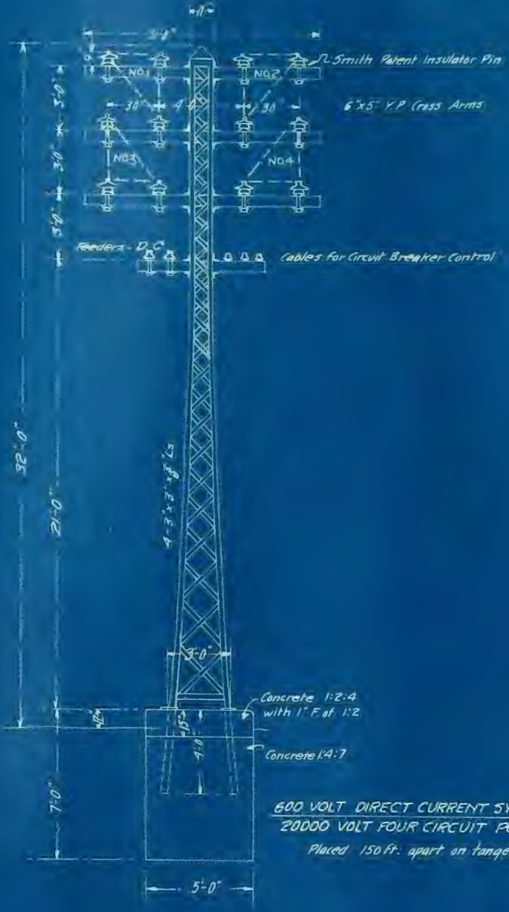
Sunday Schedule = .6 week day schedule

In a year there is assumed 20 weeks of winter load and 32 weeks of summer load. Hence total K.W. Hrs per year is 46,485,000.

TOTAL OUTPUT CURVES
DIRECT CURRENT - 600 VOLT SYSTEM
Trains operating per Provisional Schedule
Total Kilowatt Hrs per Winter Week Day 151200
" " " " Summer " " 123696
Load Factor Winter = .41
" " Summer = .38

T.W.S.

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 61



600 VOLT DIRECT CURRENT SYSTEM
20000 VOLT FOUR CIRCUIT POLE
Placed 150 ft. apart on tangent

TWS

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 62

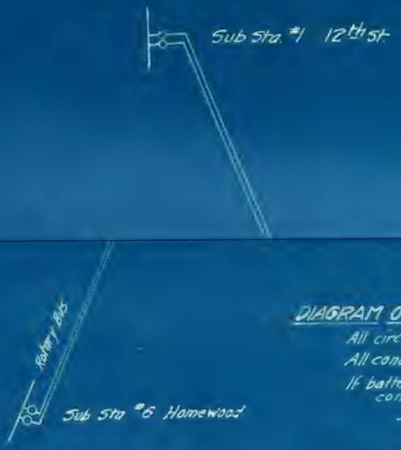


DIAGRAM OF 20000 VOLT DISTRIBUTION SYSTEM.

All circuits 3 phase. Onephase shown.

All conductors No. 00 copper, overhead

If batteries be installed at substations conductors are to be No. 1 copper

-o- H.T. Oil Switch

DISTANCES

Sub Sta. No.1	-	Sub Sta. No.2	3.1 miles
2		3	3.3
3		4	4.1
4		5	5.25
5		6	6.3
3		7	3.0
7	via So. Chgo.	4	4.3

Total:- 76.4 miles of 3phase line if company builds Power House

54.5 miles of 3phase line if company purchases power for regular service

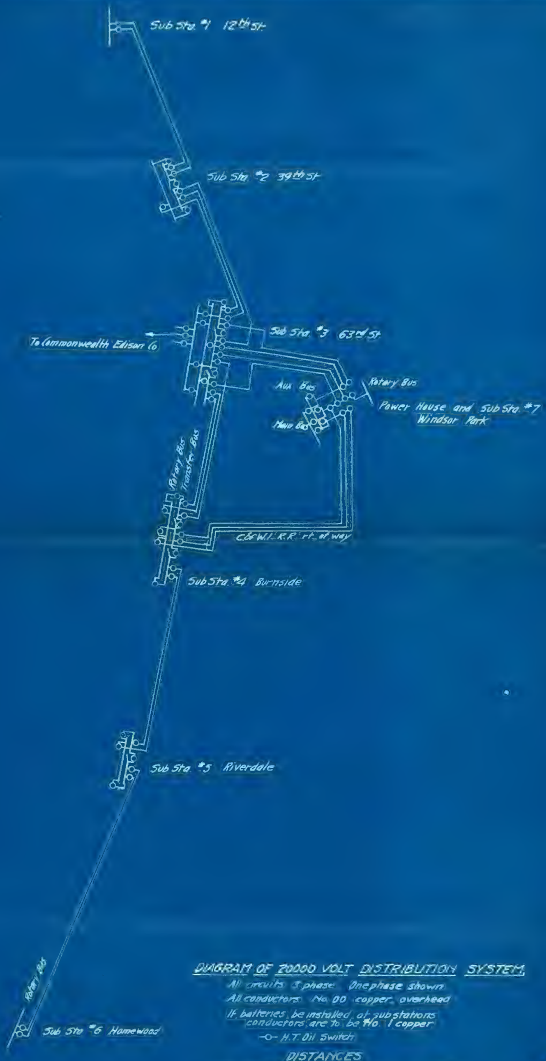


DIAGRAM OF 20000 VOLT DISTRIBUTION SYSTEM.

All circuits 3 phase. One phase shown.

All conductors No. 00 copper, overhead

If batteries be installed at substations
conductors are to be No. 1 copper

-o- H.T. Oil Switch

DISTANCES

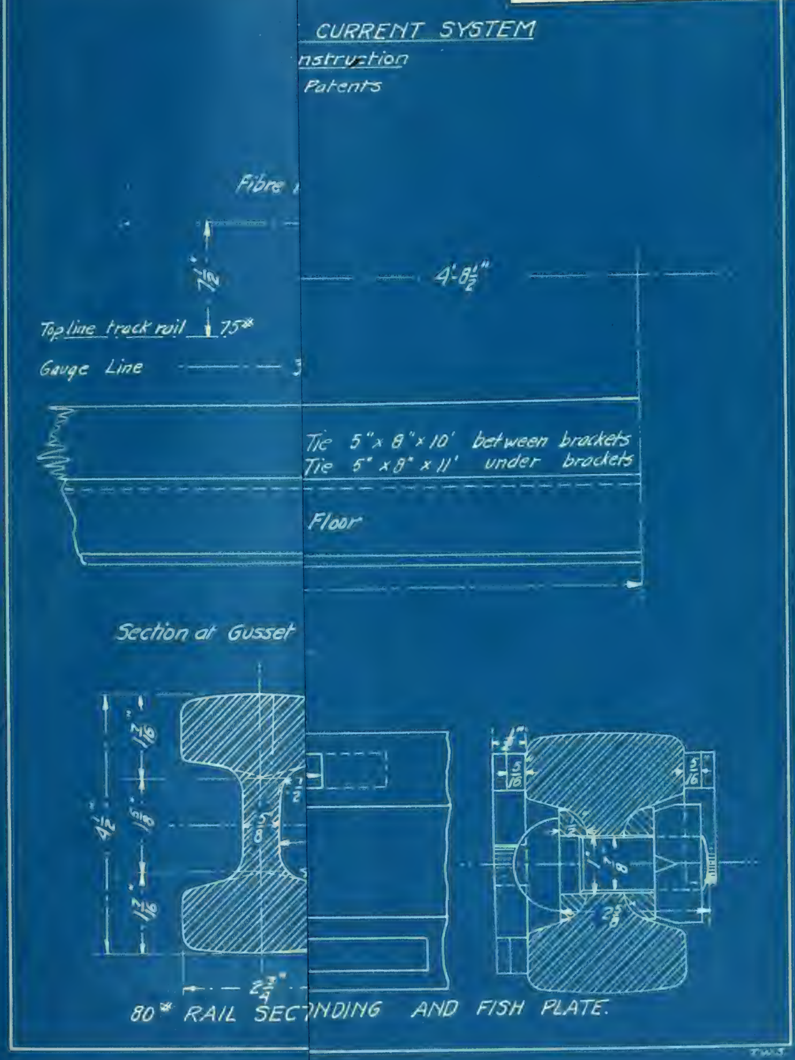
Sub Sta. No. 1	- Sub Sta. No. 2		3.1 miles
2		3	3.3
3		4	4.1
4		5	5.25
5		6	6.3
3		7	3.0
7	via So. Chgo.	4	4.3

Total = 76.4 miles of 3 phase line if company builds Power House

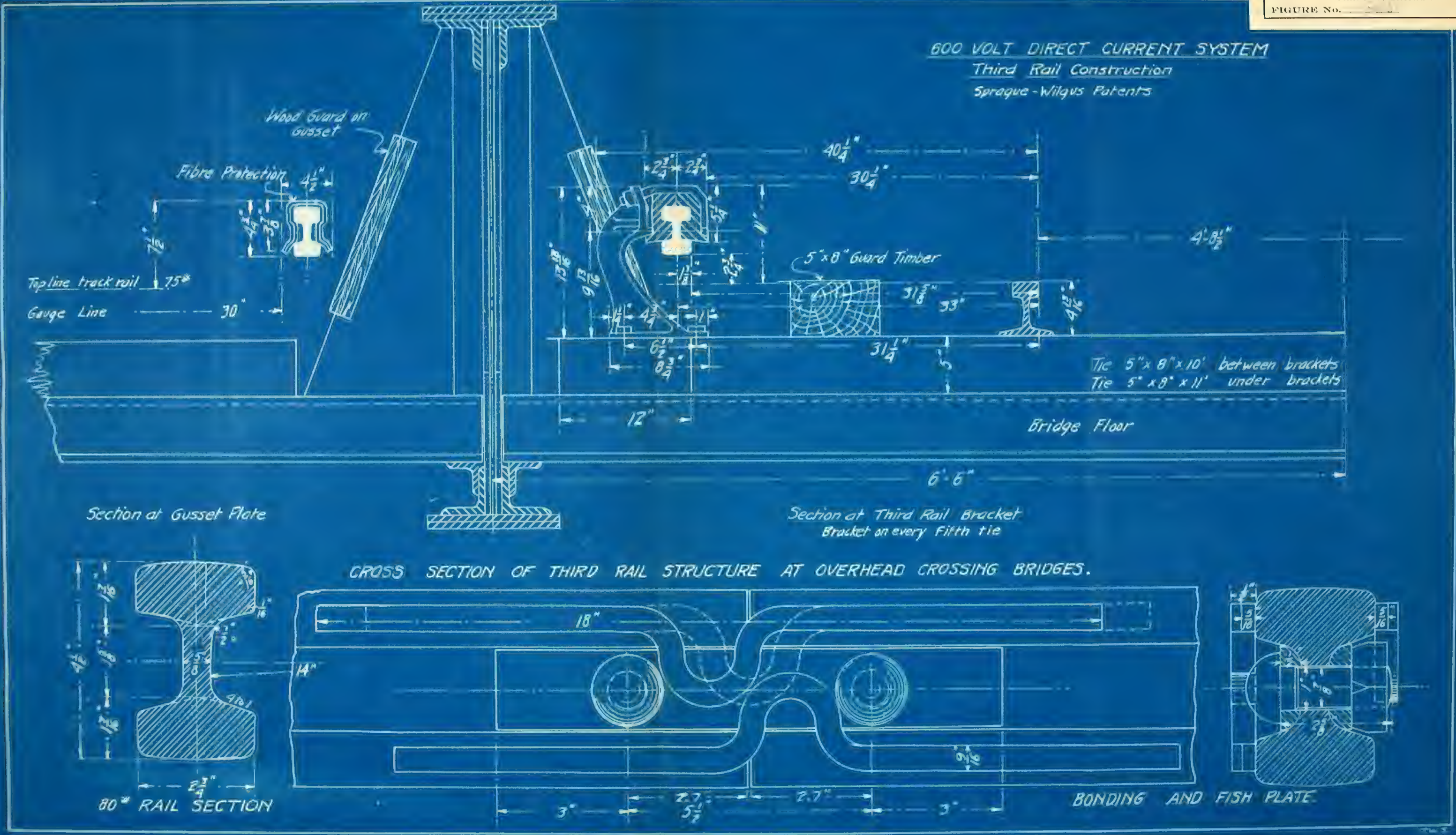
54.5 miles of 3 phase line if company purchases power for regular service

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 62

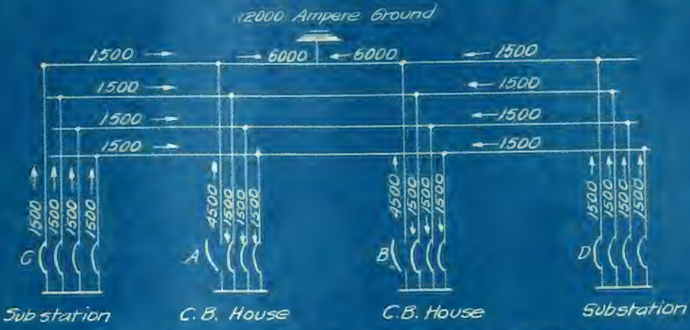
ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. [illegible]



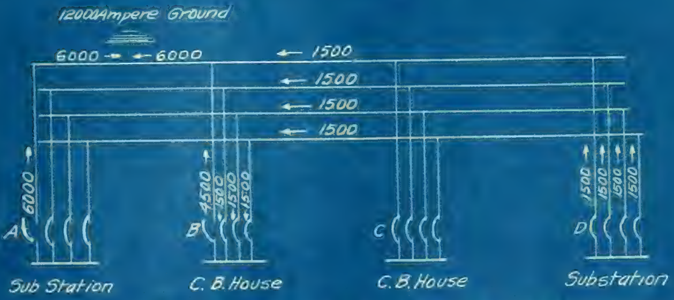
ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No.



ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 64



CASE OF GROUND ON MIDDLE SECTION
A and B Trip
with C and D following.

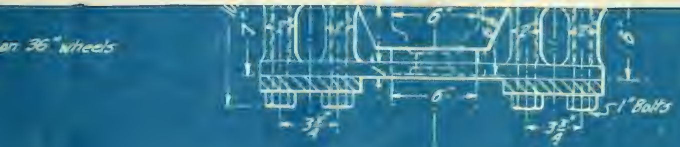


CASE OF GROUND ON END SECTION
A and B trip
with C and D following

600 VOLT DIRECT CURRENT SYSTEM
OPERATION OF CIRCUIT BREAKERS
WITH THIRD RAIL SYSTEM
Lines north of Woodlawn

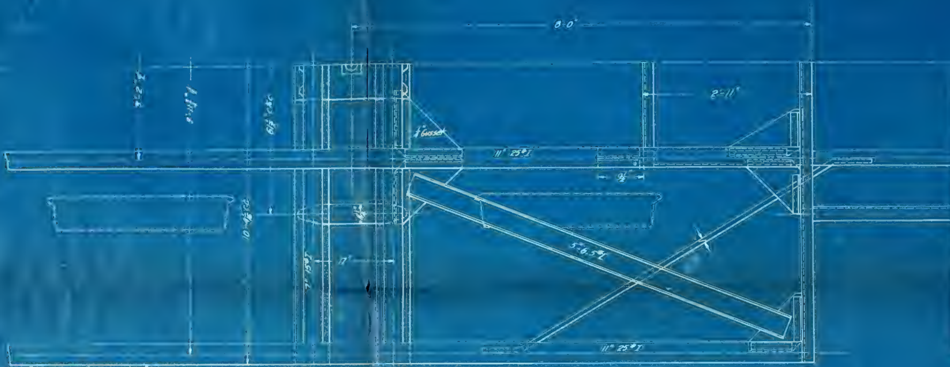
T.W.S.

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. ______

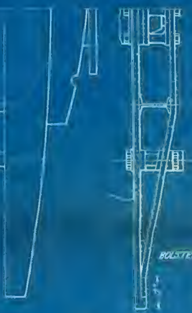


PROPOSED DESIGN FOR
RECONSTRUCTION OF MOTOR END UNDERFRAME
ON PRESENT
MULTIPLE SIDE DOOR SUBURBAN COACH
Showing new body bolster etc. to accomodate motor truck.

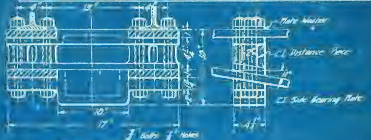
T.W.S.



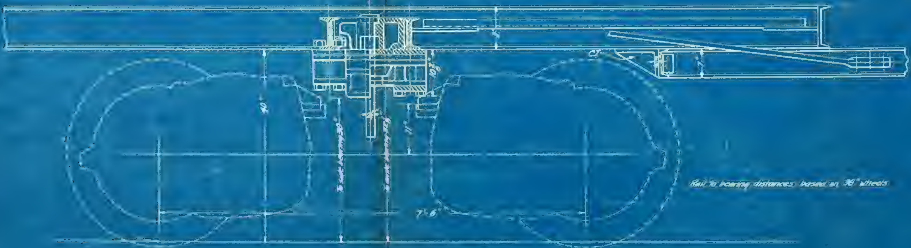
PLAN



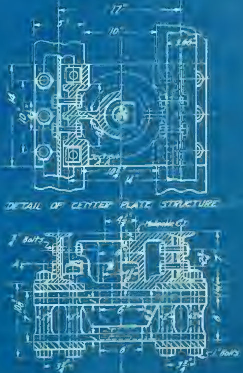
BOLSTER TRUSS



DETAIL OF SIDE BEARING



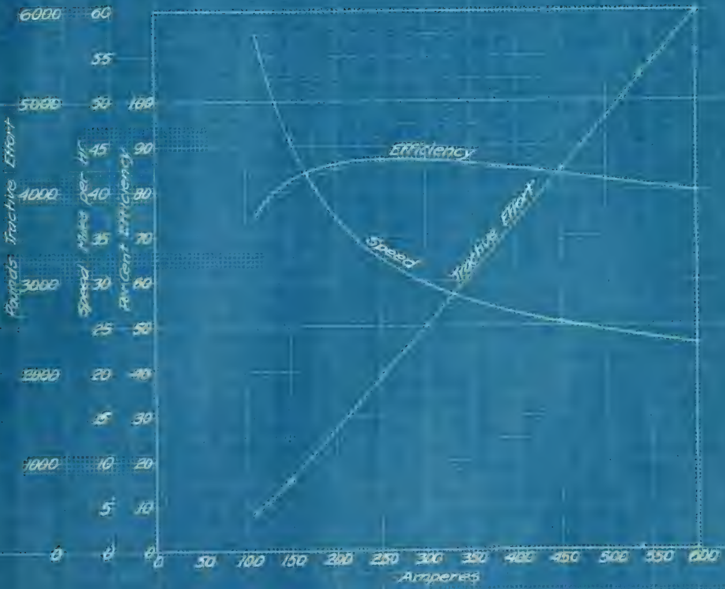
ELEVATION



DETAIL OF CENTER PLATE STRUCTURE

PROPOSED DESIGN FOR
RECONSTRUCTION OF MOTOR END UNDERFRAME
ON PRESENT
MULTIPLE SIDE DOOR SUBURBAN COACH
Showing new body bolster etc. to accomodate motor truck.

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. [illegible]



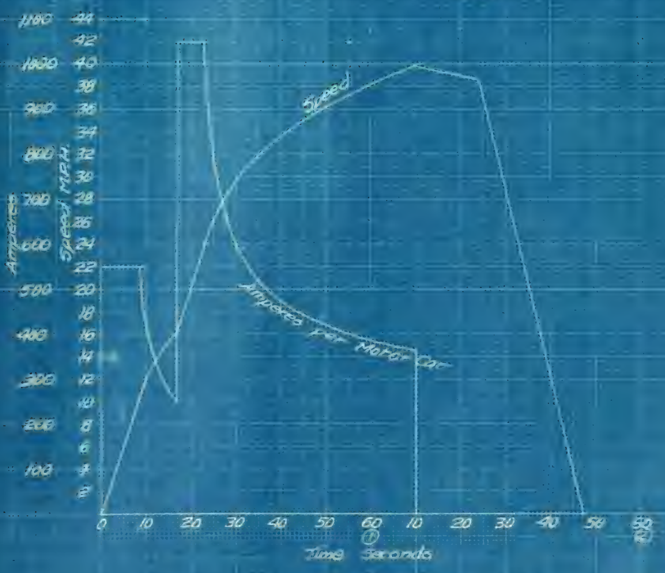
ESTIMATED CHARACTERISTIC CURVES

150 HP Frame Size Interpole Motor wound to operate as 360 HP motor. Cooled by forced ventilation.

570 Volts 36 inch wheels

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 37

3 CAR TRAIN
K.W. Hrs for run 11.70
Avg. K.W. per Train 354
Blower Motors 4
358



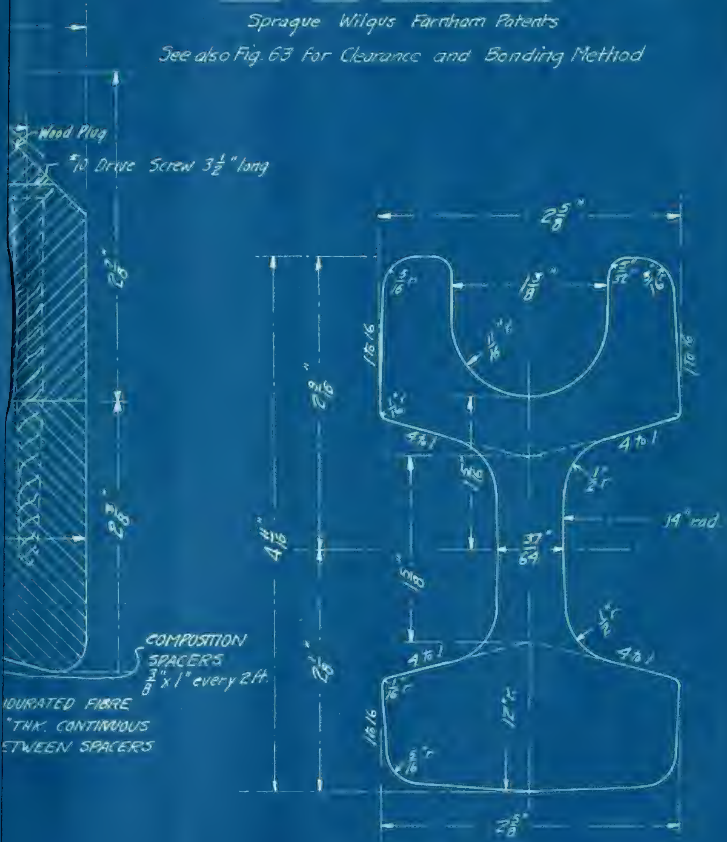
TYPICAL RUN 0.815 MILES
3 Car Train
2 Motor Cars 1 Trail Car
On each motor car
2 Motors with forced draft
36" Wheels 570 volts
See Fig for motor characteristics

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 62

1200 VOLT DIRECT CURRENT SYSTEM
THIRD RAIL CONSTRUCTION

Sprague Wilgus Farnham Patents

See also Fig. 63 for Clearance and Bonding Method

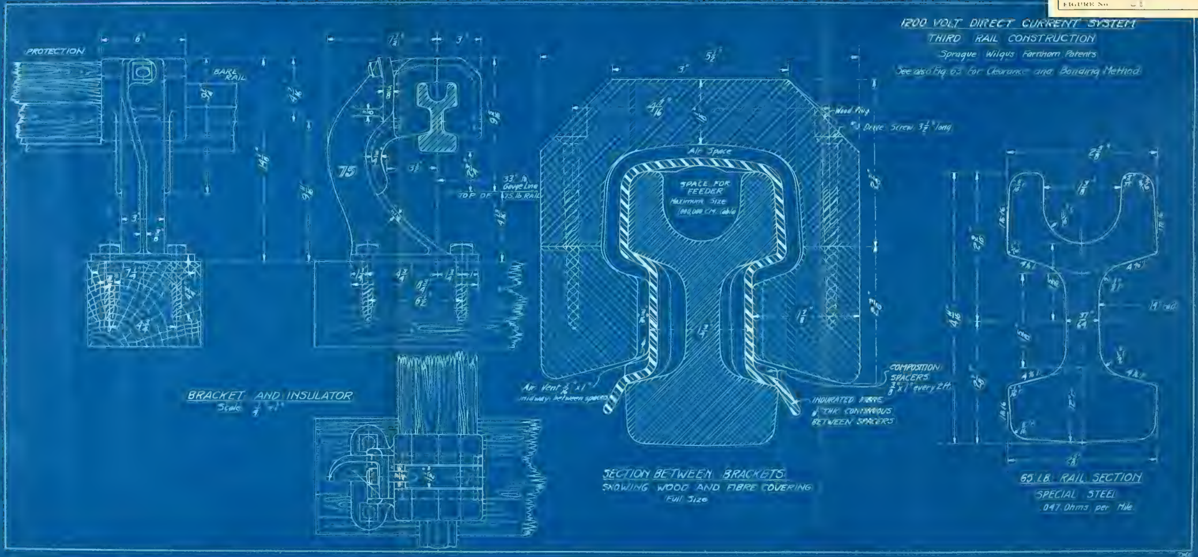


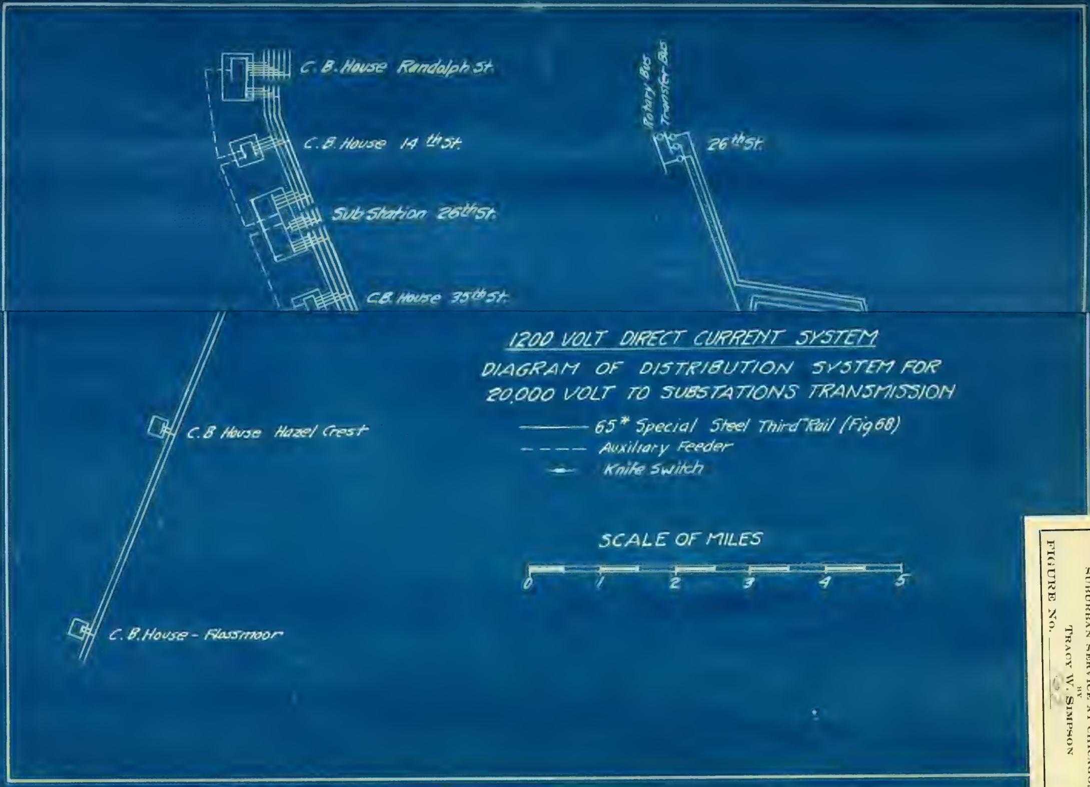
65 LB. RAIL SECTION

SPECIAL STEEL

.047 Ohms per Mile.

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO ILL.
BY
TRACY W. SIMPSON
FIGURE No. [illegible]

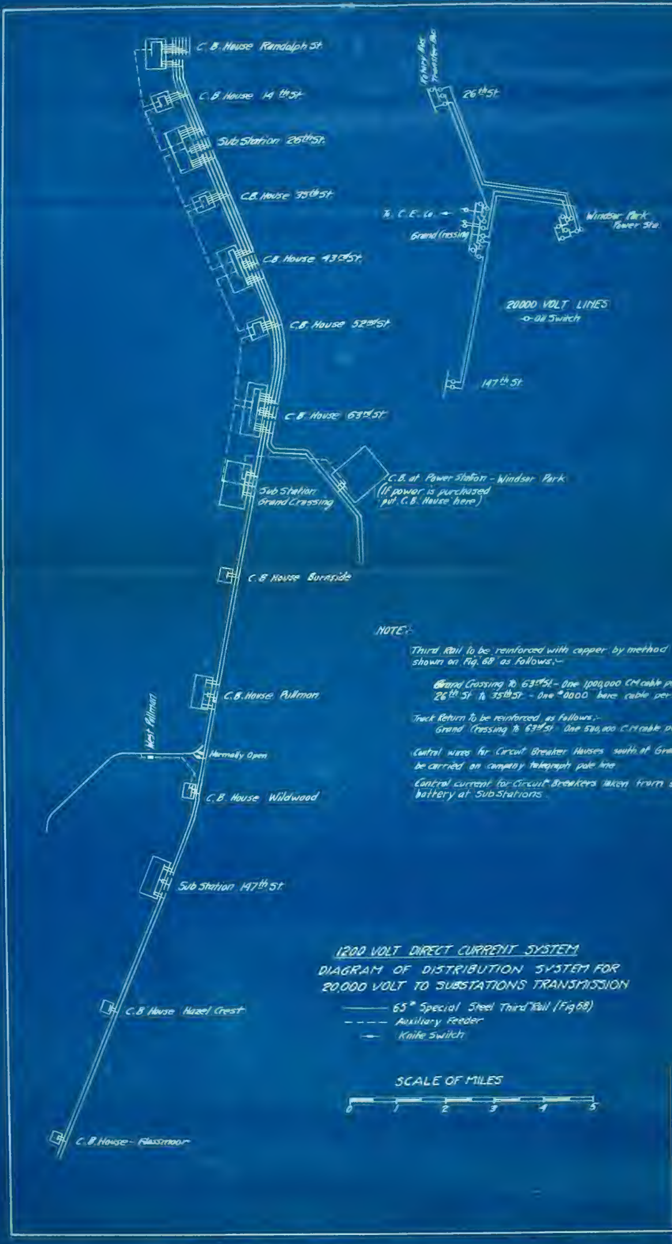




1200 VOLT DIRECT CURRENT SYSTEM

DIAGRAM OF DISTRIBUTION SYSTEM FOR 20,000 VOLT TO SUBSTATIONS TRANSMISSION

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. ______



NOTE:-

Third Rail to be reinforced with copper by method shown on Fig. 68 as follows:-

Grand Crossing to 63rd St. - One 1,000,000 C.M. cable per track
26th St. to 35th St. - One #0000 bare cable per track

Track Return to be reinforced as follows:-
Grand Crossing to 63rd St. One 500,000 C.M. cable per track

Control wires for Circuit Breaker Houses south of Grand X to be carried on company telegraph pole line

Control current for Circuit Breakers taken from small battery at Sub Stations

1200 VOLT DIRECT CURRENT SYSTEM

DIAGRAM OF DISTRIBUTION SYSTEM FOR
20,000 VOLT TO SUBSTATIONS TRANSMISSION

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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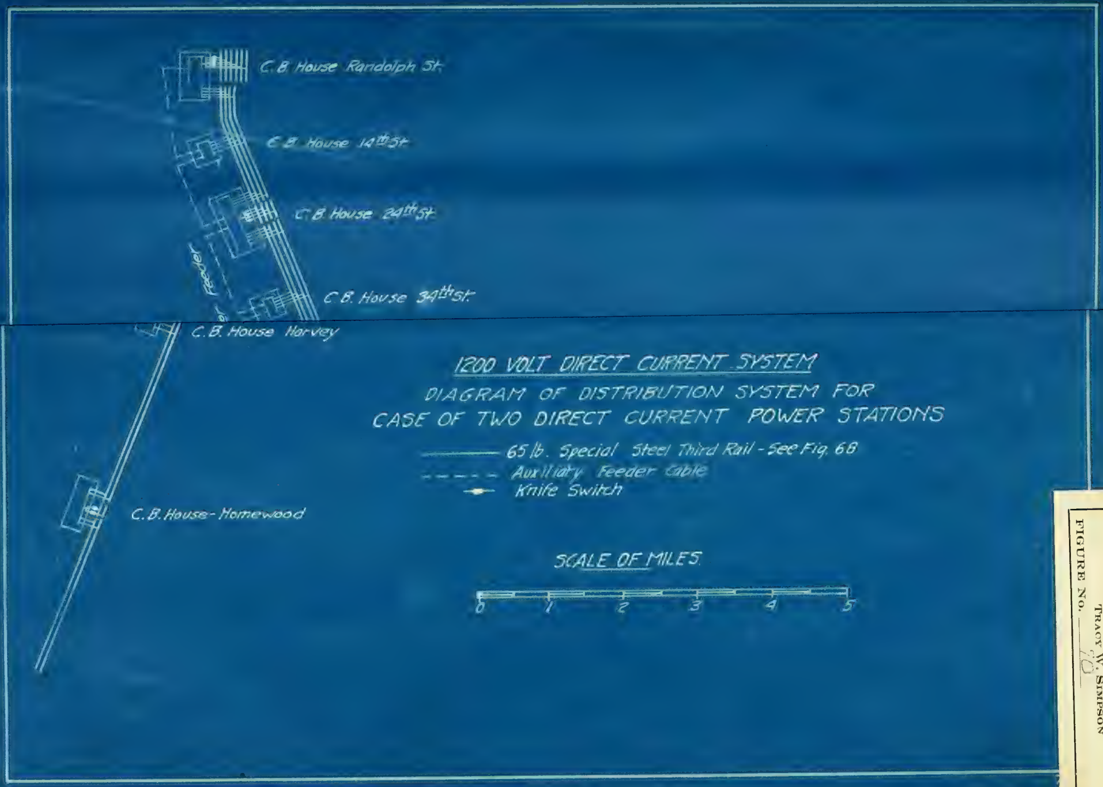
FIGURE No.



1200 VOLT DIRECT CURRENT SYSTEM

DIAGRAM OF DISTRIBUTION SYSTEM FOR
CASE OF TWO DIRECT CURRENT POWER STATIONS

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SUBURBAN SERVICE AT CHICAGO, ILL.
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FIGURE No. 10

ELECTRIFICATION PROJECT
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SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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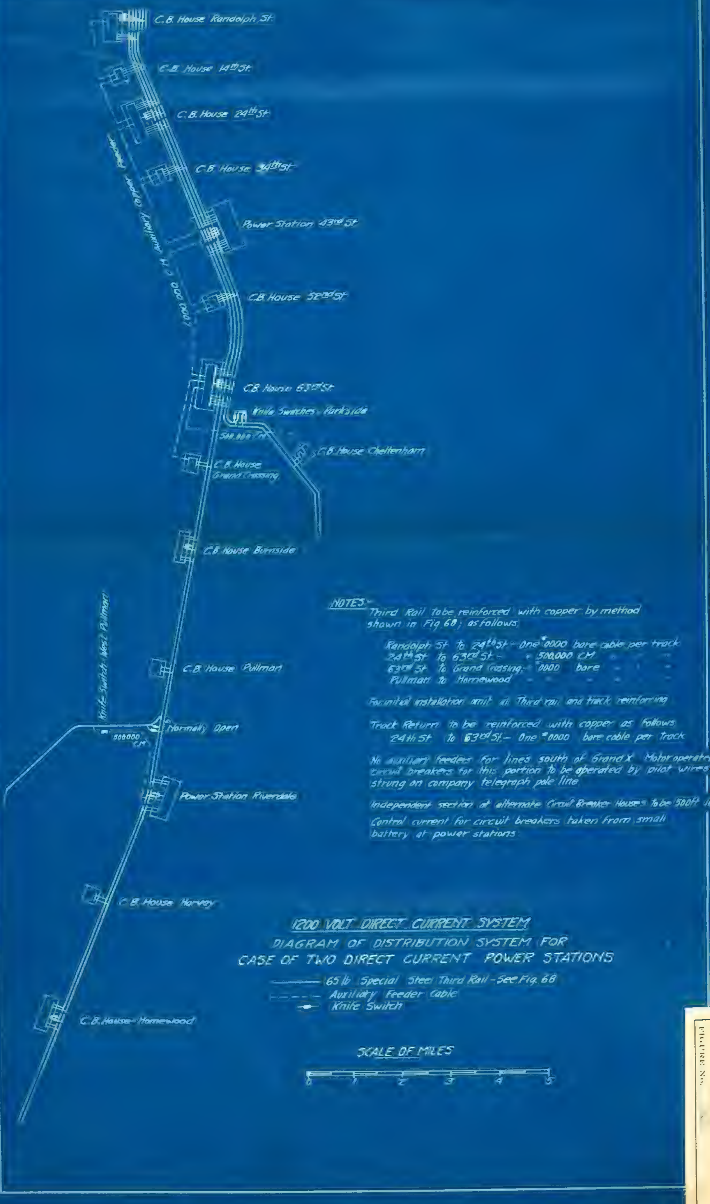
FIGURE No.



NOTES:- Third Rail to be reinforced with copper by method shown in Fig 68; as follows;

Randolph St to 24th St - One #0000 bare cable per track
24th St to 63rd St - " 500,000 C.M. " " "
63rd St to Grand Crossing - " 0000 bare " " "
Pullman to Homewood " " " " " "

For initial installation omit all Third rail and track reinforcing.

Track Return to be reinforced with copper as follows
24th St to 63rd St. - One #0000 bare cable per Track

No auxiliary feeders for lines south of Grand X. Motor operated circuit breakers for this portion to be operated by pilot wires strung on company telegraph pole line.

Independent section at alternate Circuit Breaker Houses to be 500 ft long.

Control current for circuit breakers taken from small battery at power stations.

1200 VOLT DIRECT CURRENT SYSTEM

DIAGRAM OF DISTRIBUTION SYSTEM FOR
CASE OF TWO DIRECT CURRENT POWER STATIONS

ELECTRIFICATION PROJECT
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SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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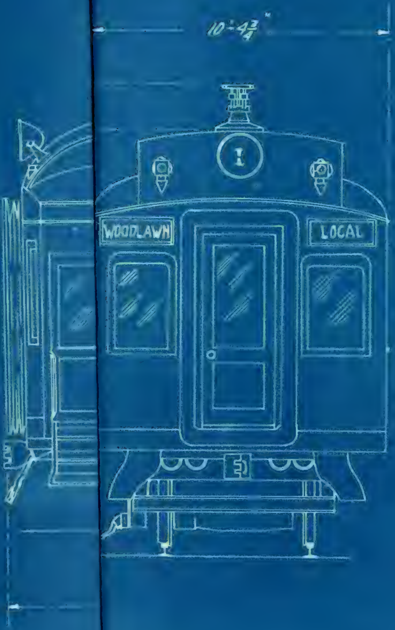
FIGURE No. 71



ECT CURRENT SYSTEM

SUBURBAN SERVICE

2 - 300 H.P. MOTORS
FORCED VENTILATION

car train comprising two motor
s 165 Tons.

¼" = 1 ft.

T.W.S.

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THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO ILL.
BY
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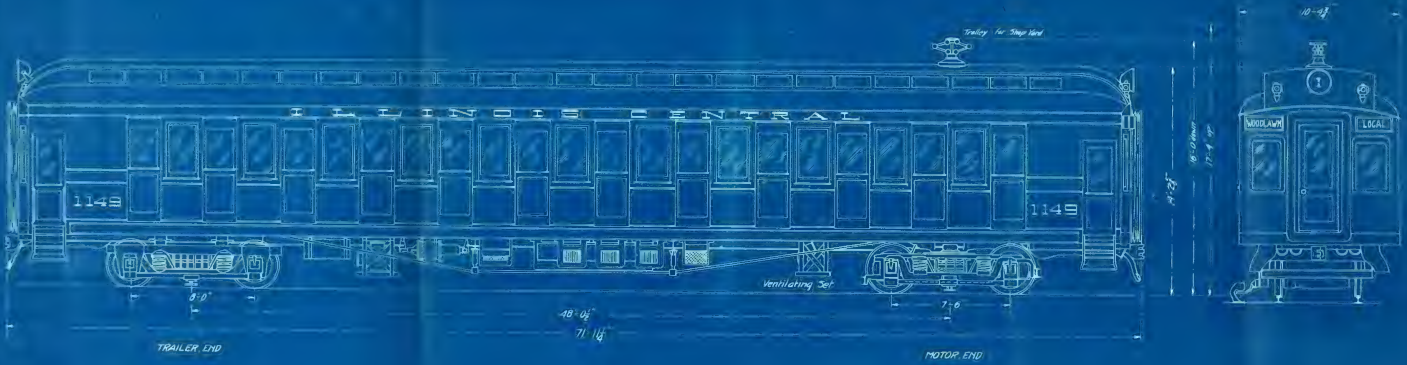
FIGURE No.

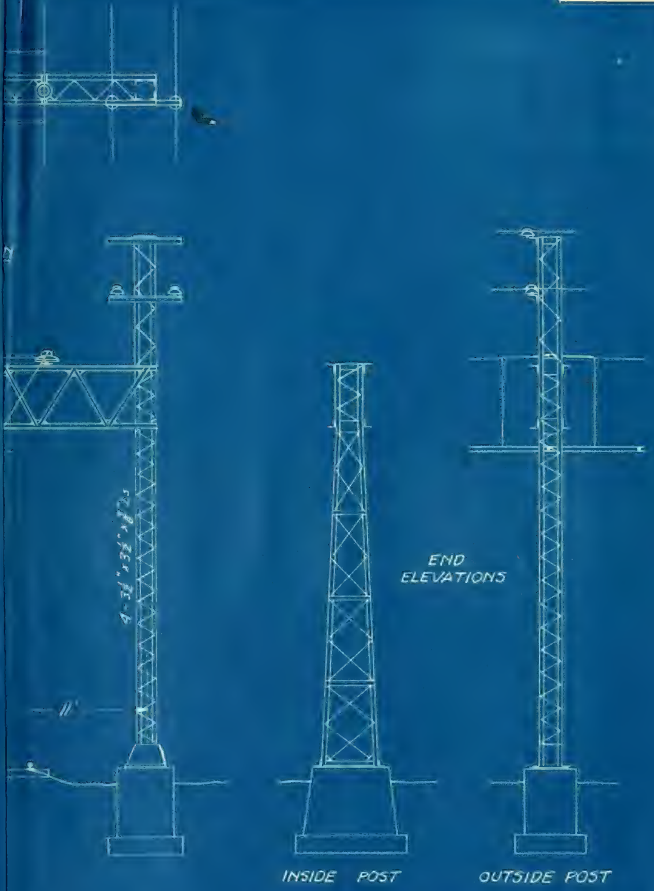


1200 VOLT DIRECT CURRENT SYSTEM
MOTOR CAR FOR SUBURBAN SERVICE
EQUIPPED WITH 2-300 H.P. MOTORS
PROVIDED WITH FORCED VENTILATION

Total weight loaded of 3 car train comprising two motor cars and one trail car is 165 Tons

Scale $\frac{1}{4}$" = 1 ft.

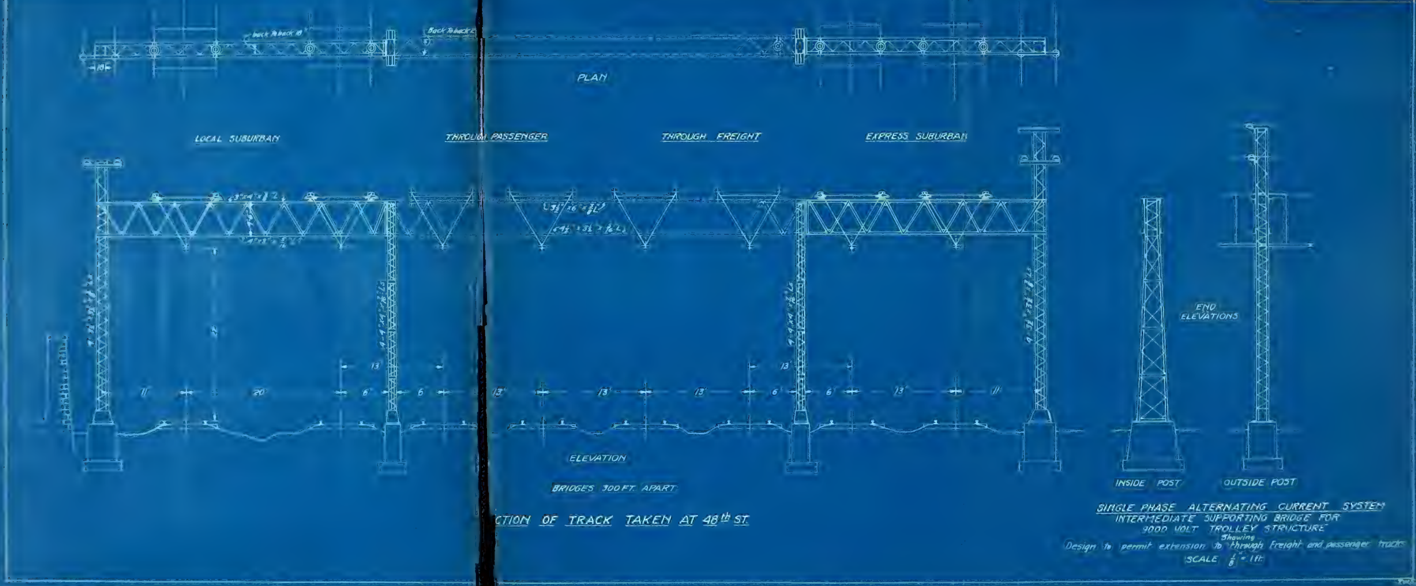
ELECTRIFICATION PROJE
THE ILLINOIS CENTRAL RAILR
SUBURBAN SERVICE AT CHICAGO
BY
TRACY W. SIMPSON
FIGURE No. 72



SINGLE PHASE ALTERNATING CURRENT SYSTEM
INTERMEDIATE SUPPORTING BRIDGE FOR
9000 VOLT TROLLEY STRUCTURE
Showing
Design to permit extension to through freight and passenger tracks
SCALE $\frac{1}{8}$" = 1 ft.

T.W.S.

SUBURBAN SERVICE AT CHICAGO,
BY
TRACY W. SIMPSON
FIGURE No. 72

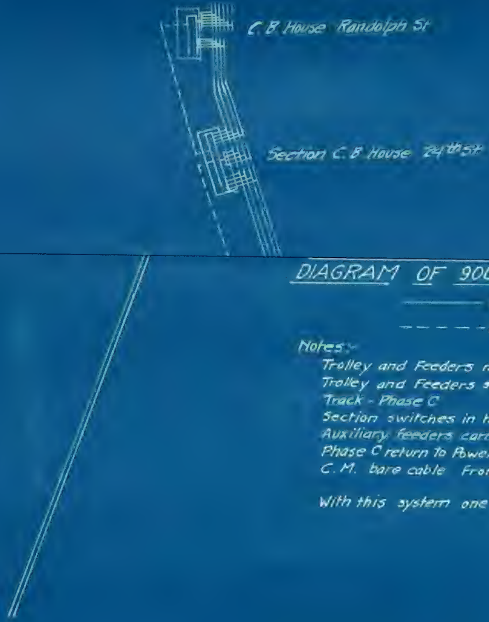


BRIDGES 300 FT. APART

CTION OF TRACK TAKEN AT 48th ST.

SINGLE PHASE ALTERNATING CURRENT SYSTEM
INTERMEDIATE SUPPORTING BRIDGE FOR
9000 VOLT TROLLEY STRUCTURE
Showing
Design to permit extension to through Freight and passenger tracks
SCALE $\frac{1}{8}$" = 1 ft.

DIAGRAM OF 9000 VOLT TROLLEY AND FEEDERS



—— 9000 Volt Trolley

- - - - Feeder - #0000 Except where specified.

Notes:-

Trolley and Feeders north of 63rd St. on Phase A
Trolley and Feeders south of 63rd St. on Phase B
Track - Phase C
Section switches in houses, not on bridges.
Auxiliary feeders carried by bridge structure (Fig. 72)
Phase C return to Power Station to be reinforced with one 1,000,000 C.M. bare cable from 63rd St. to Windsor Park.

With this system one rail of track return can be used for signals

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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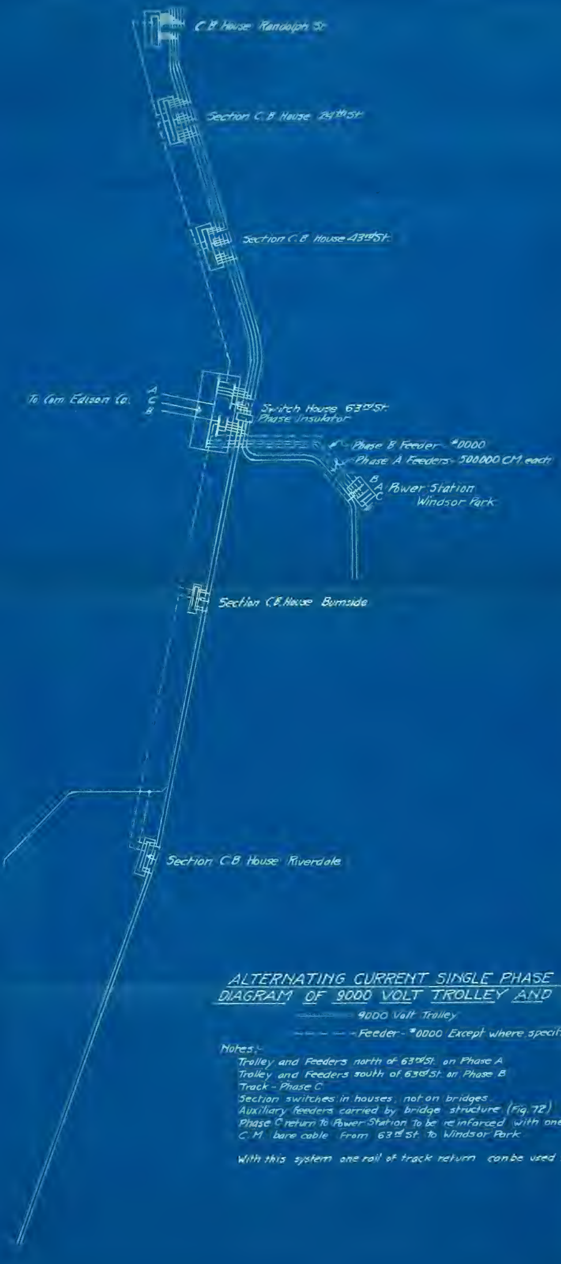
FIGURE No. 73


C.B. House Randolph St.
Section C.B. House 24th St.
Section C.B. House 43rd St.
To Com. Edison Co.
A
C
B
Switch House 63rd St.
Phase Insulator
Phase B Feeder - #0000
Phase A Feeders - 500000 C.M. each
B
A
C
Power Station
Windsor Park
Section C.B. House Burnside
Section C.B. House Riverdale

ALTERNATING CURRENT SINGLE PHASE SYSTEM
DIAGRAM OF 9000 VOLT TROLLEY AND FEEDERS

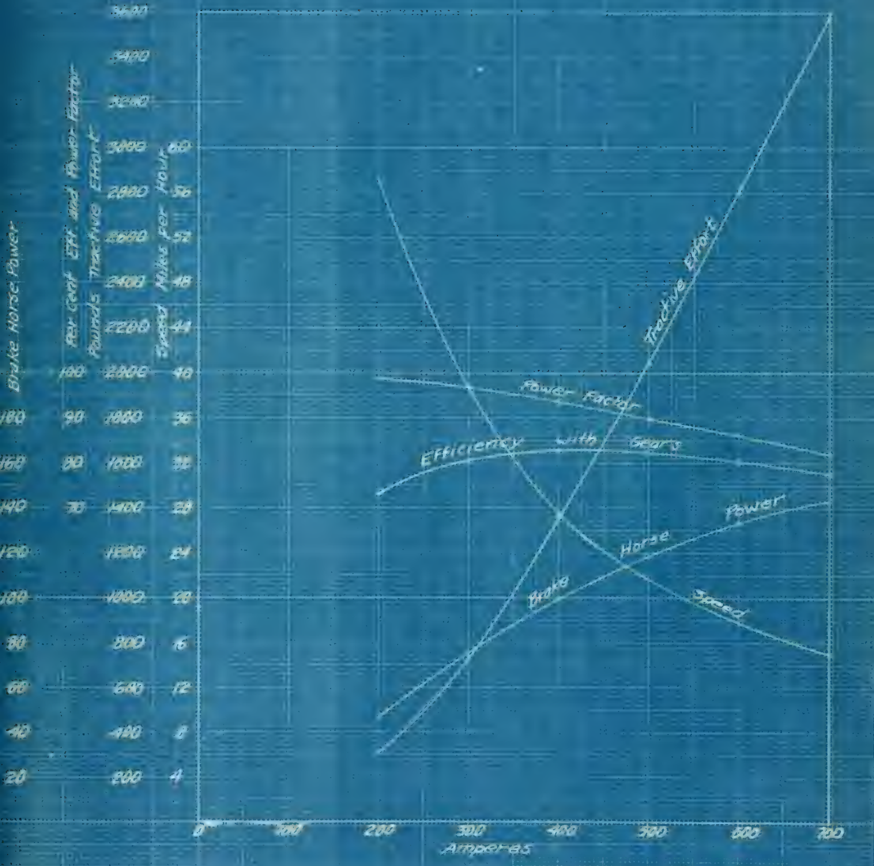
9000 Volt Trolley
Feeder - #0000 Except where specified

Notes:-
Trolley and Feeders north of 63rd St. on Phase A
Trolley and Feeders south of 63rd St. on Phase B
Track - Phase C
Section switches in houses, not on bridges.
Auxiliary feeders carried by bridge structure (Fig. 72)
Phase C return to Power Station to be re inforced with one 1,000,000 C.M. bare cable from 63rd St. to Windsor Park

With this system one rail of track return can be used for signals

SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 73

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON
FIGURE No. 74



CHARACTERISTIC CURVES
The Westinghouse No. 148A Rwy. Motor
25 Cycles 240 volts
Gear Ratio $\frac{71}{20}$ = 3.55 37½ in wheels

From Wgh. E. & M. Co. #54352

Rating:–
One Hr. 540 Amps at 240 volts
Contin. 275 Amps at 240 volts

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ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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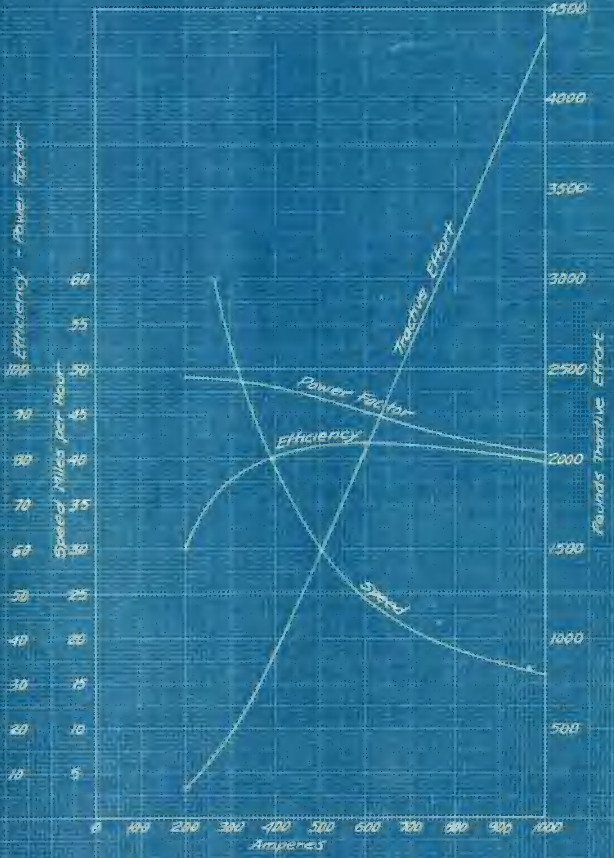
FIGURE No. 75



CHARACTERISTIC CURVES
Westinghouse No. 133 Ry. Motor
Single Phase 25 cycles
Wheel diam 38in. Gear Ratio $66/23 = 2.87$
Volts at Terminals 215

TWS

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
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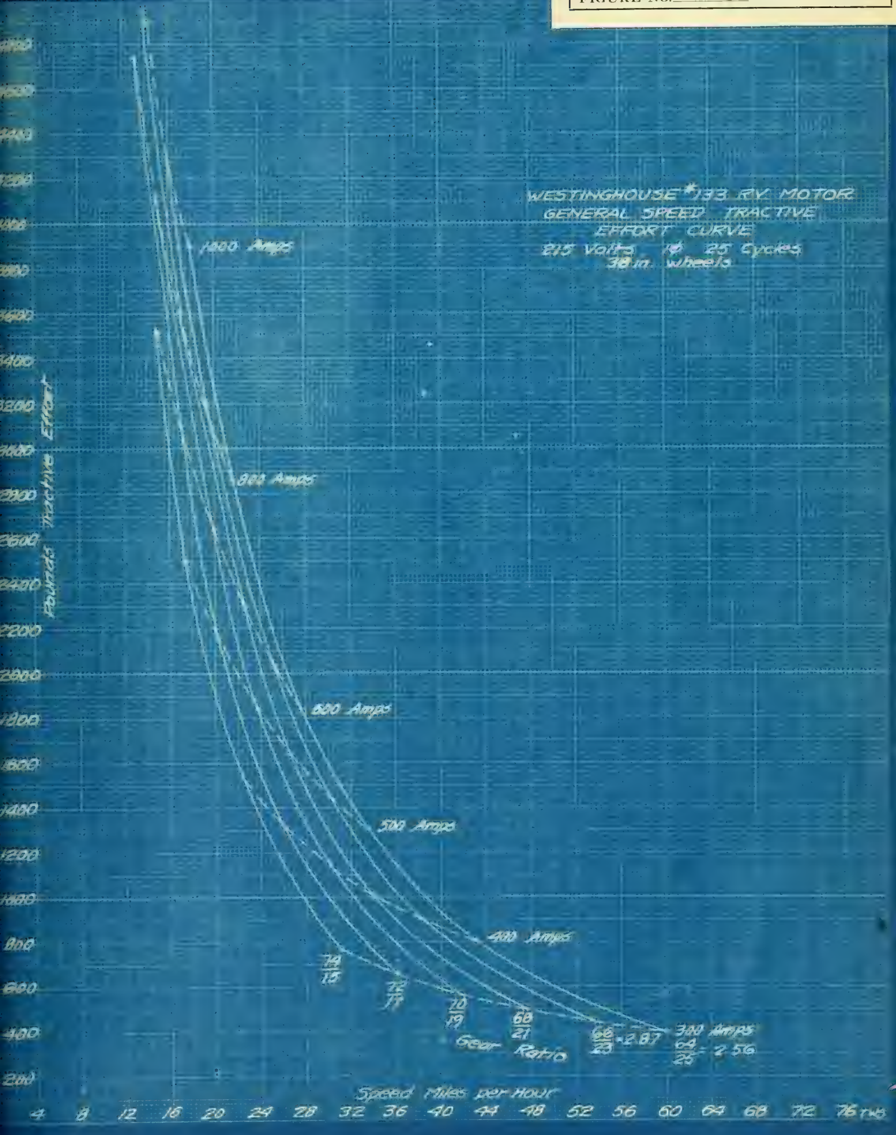
FIGURE No. 76



ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
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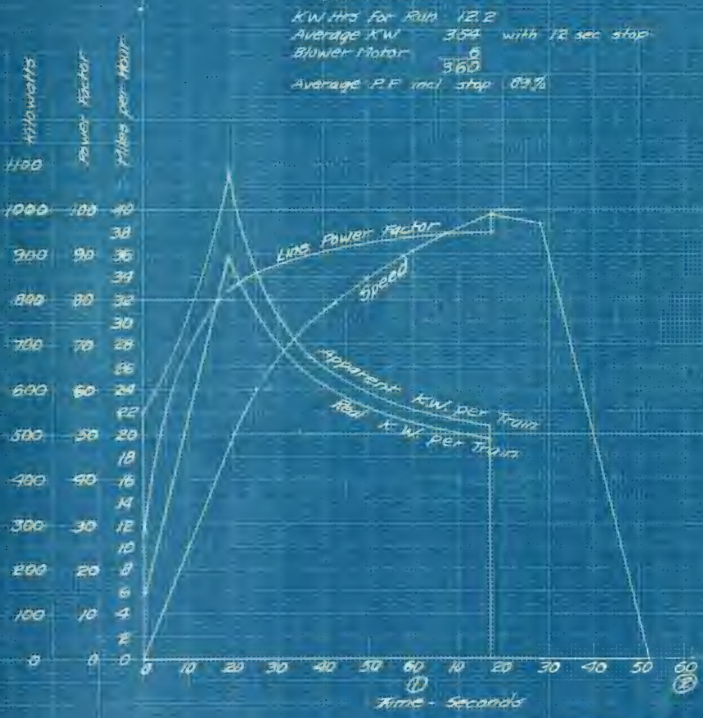
FIGURE No. 77

3 CAR TRAIN
KW Hrs for Run 12.2
Average KW 354 with 12 sec stop
Blower Motor 6
360
Average P.F. incl stop 69%



TYPICAL RUN 0.815 MILES
2 - No. 133 Motors per Car
Single Phase 25 Cycle
38" Wheels Gear Ratio $\frac{66}{23}$ = 2.87
215 Volts - Forced Draft

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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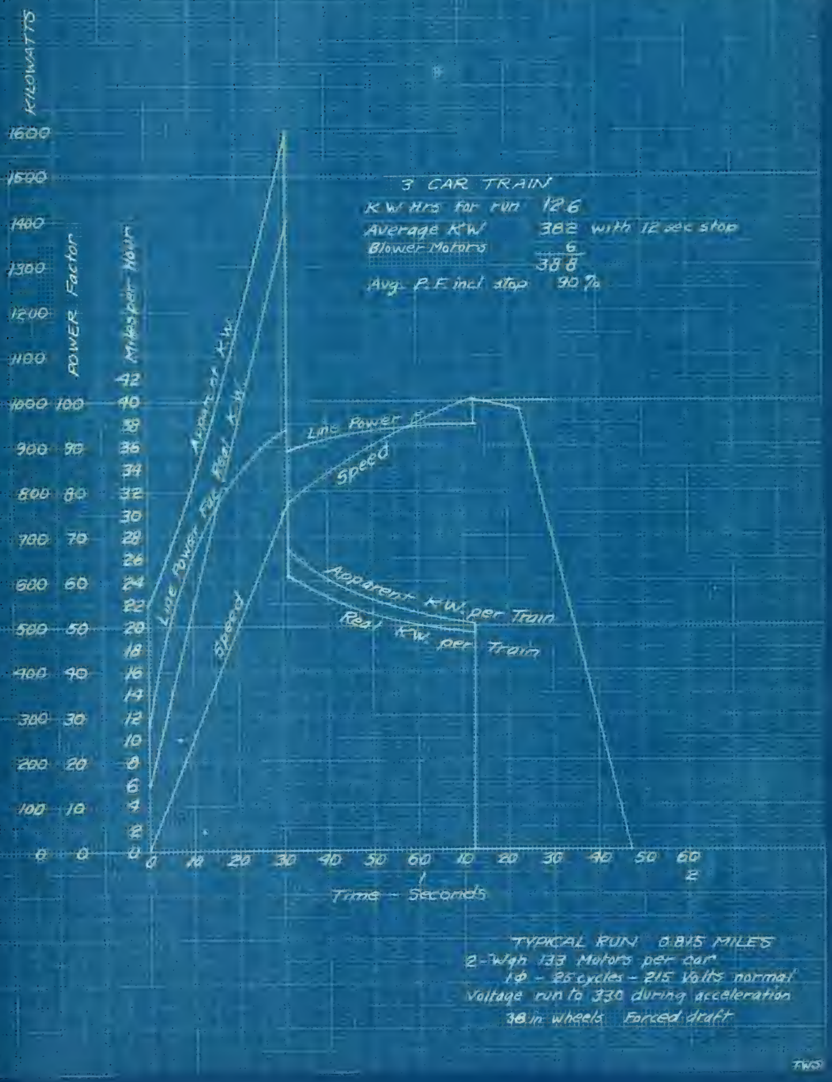
FIGURE No. 78



3 CAR TRAIN
K.W. Hrs. for run 12.6
Average K.W. 382 with 12 sec stop
Blower Motors 6
388
Avg. P.F. incl. stop 90 %

TYPICAL RUN 0.815 MILES
2-Wgh 133 Motors per car
1φ - 25 cycles - 215 Volts normal
Voltage run to 330 during acceleration
38 in. wheels Forced draft

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THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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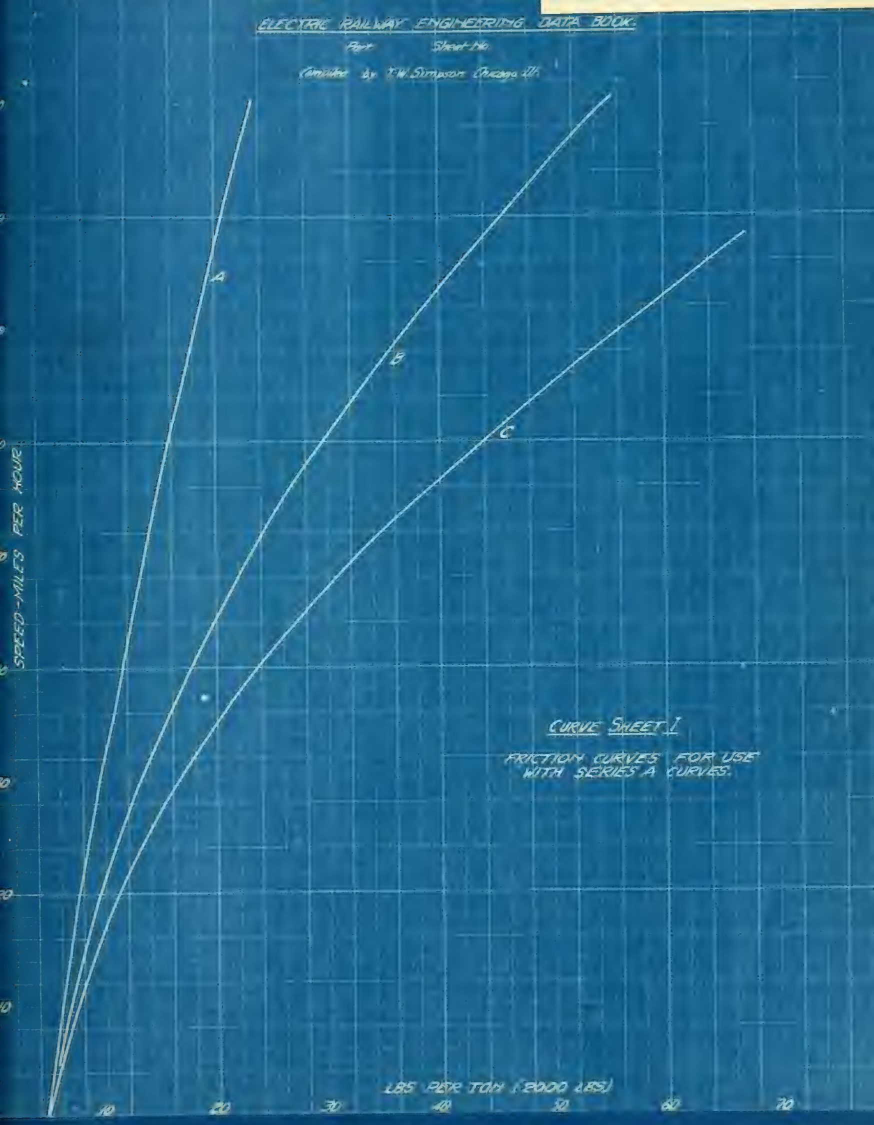
FIGURE No. 73



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SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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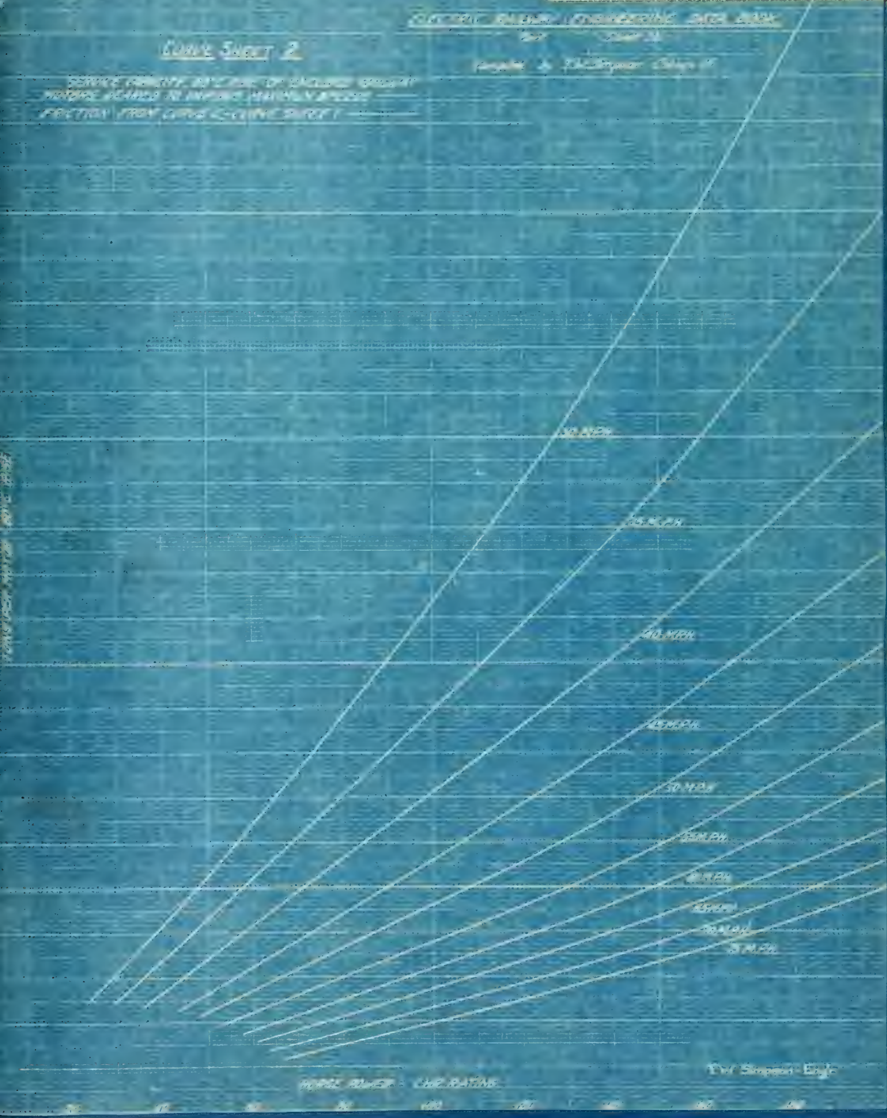
FIGURE No. 20



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SUBURBAN SERVICE AT CHICAGO, ILL.
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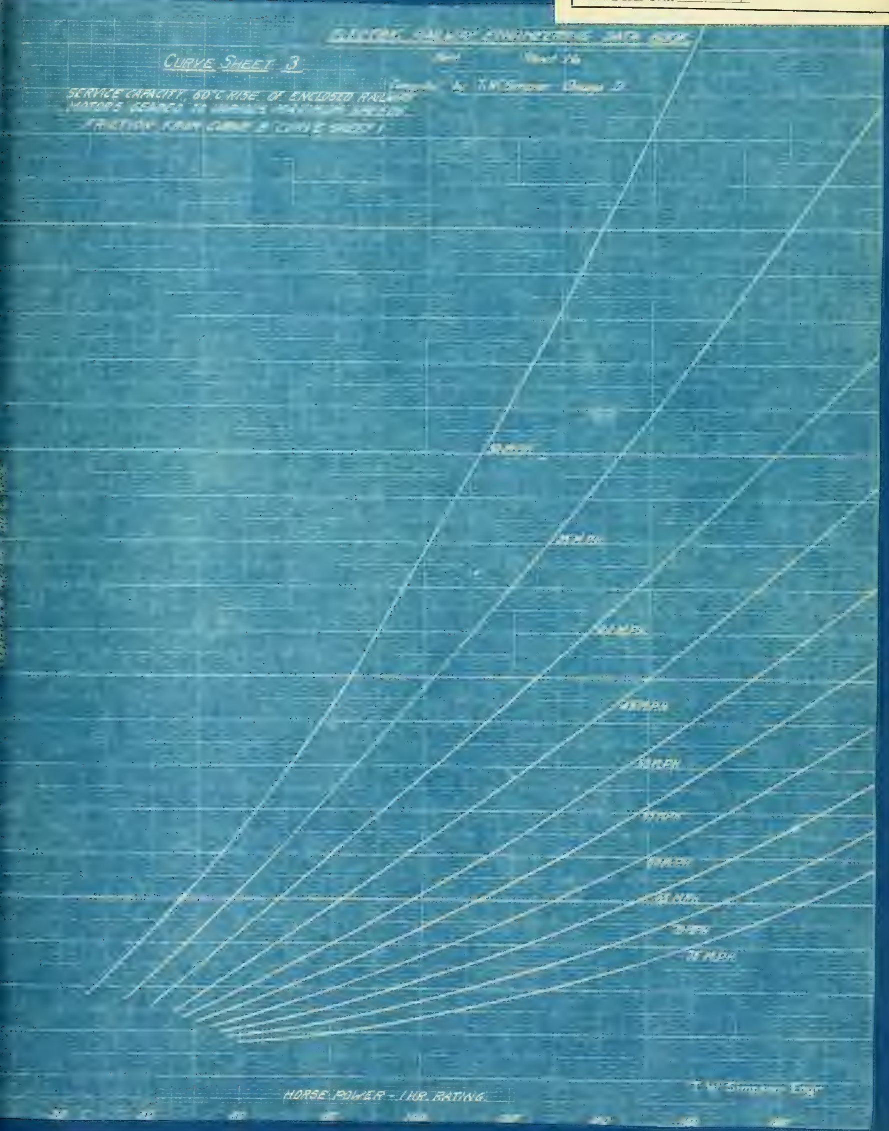
FIGURE No. 21



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SUBURBAN SERVICE AT CHICAGO, ILL.
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FIGURE No. 72

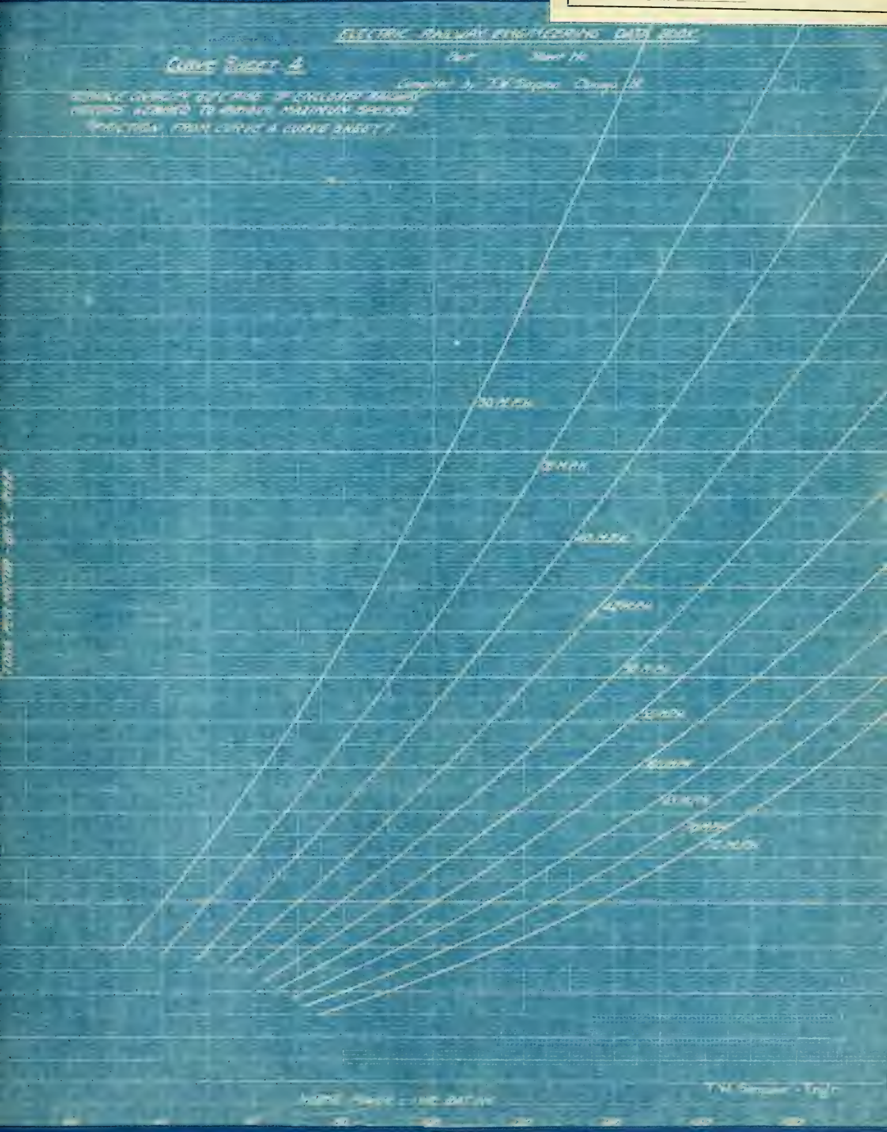

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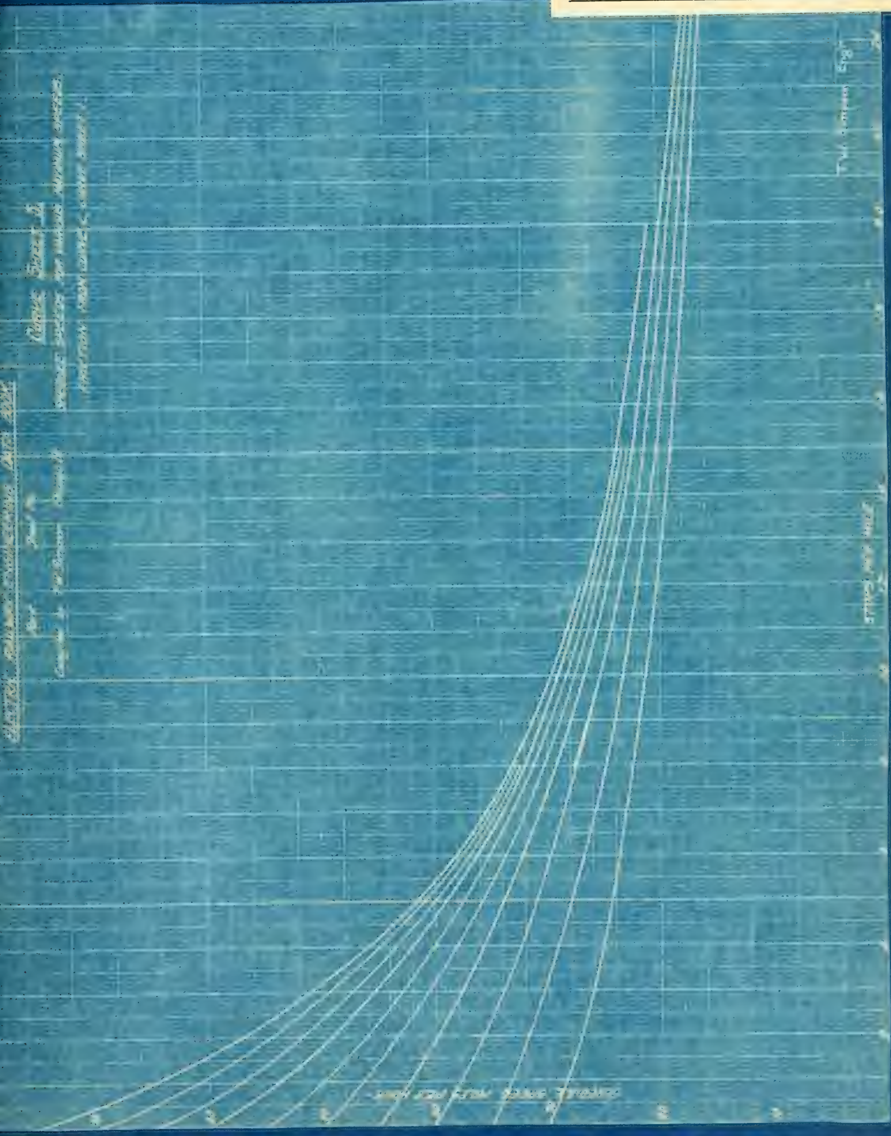
FIGURE No. 83



ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
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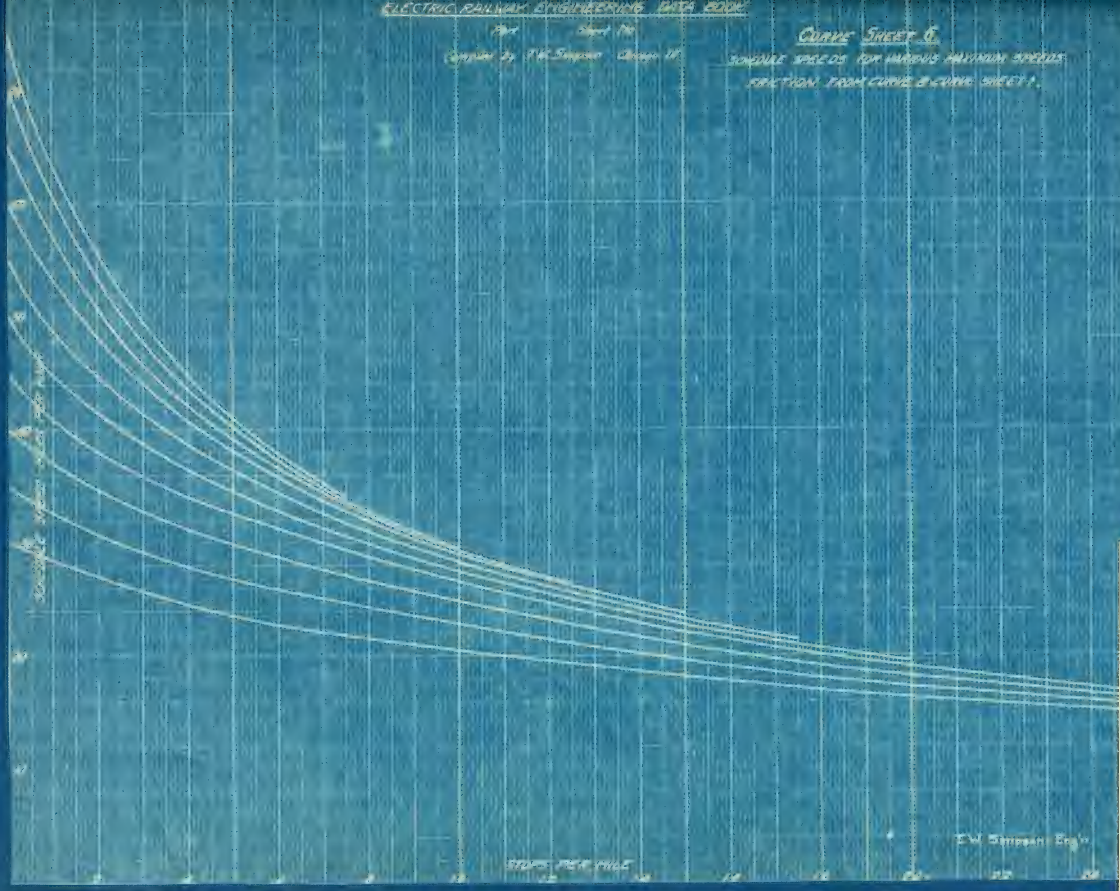
FIGURE No. 84



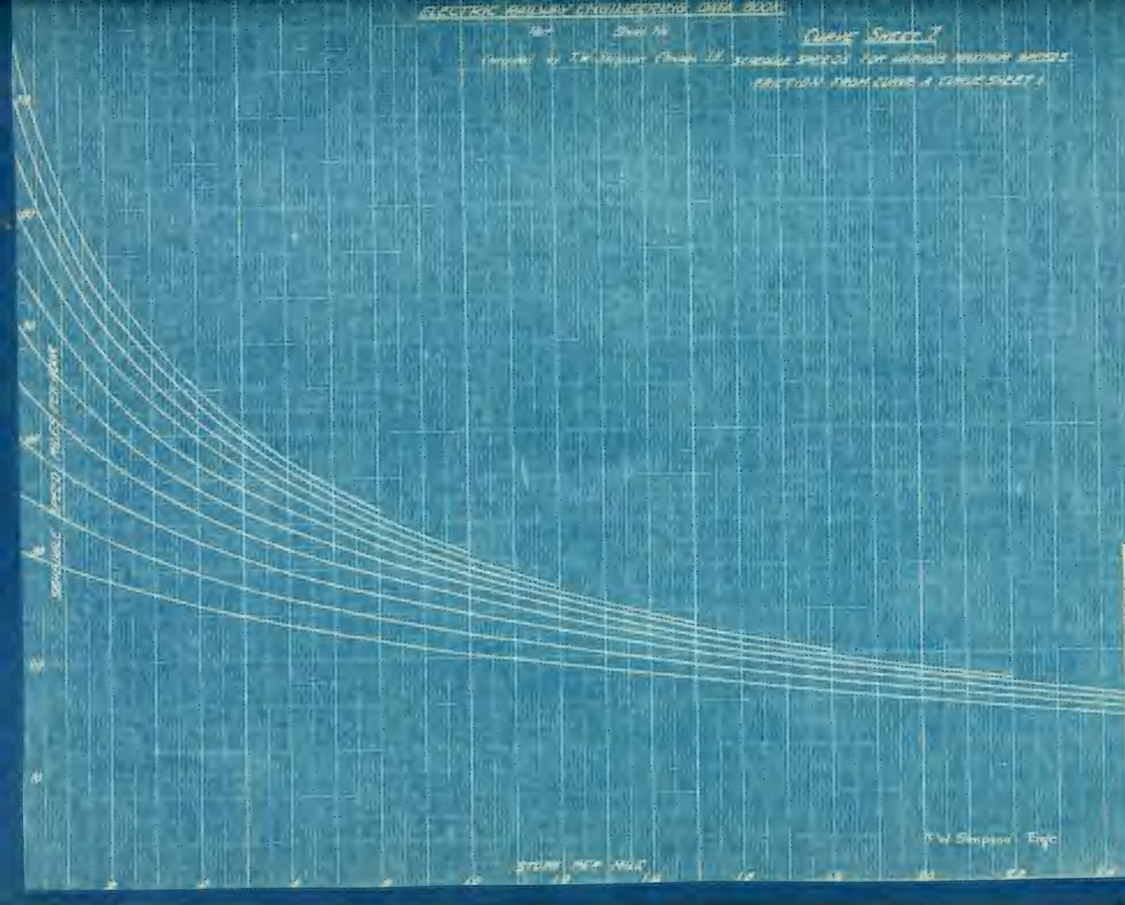


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FIGURE No. 85

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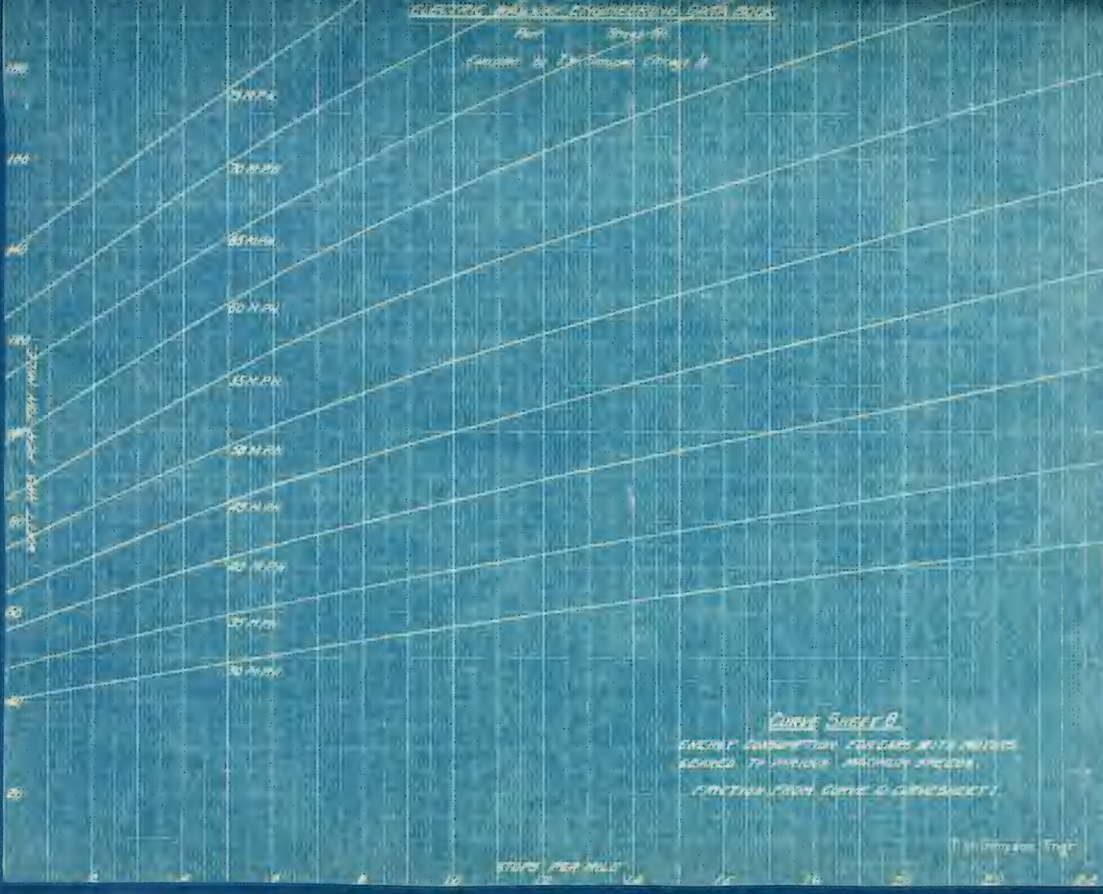
FIGURE No. 26



Curve Sheet 8.

Energy consumption for cars with motors geared to various maximum speeds.

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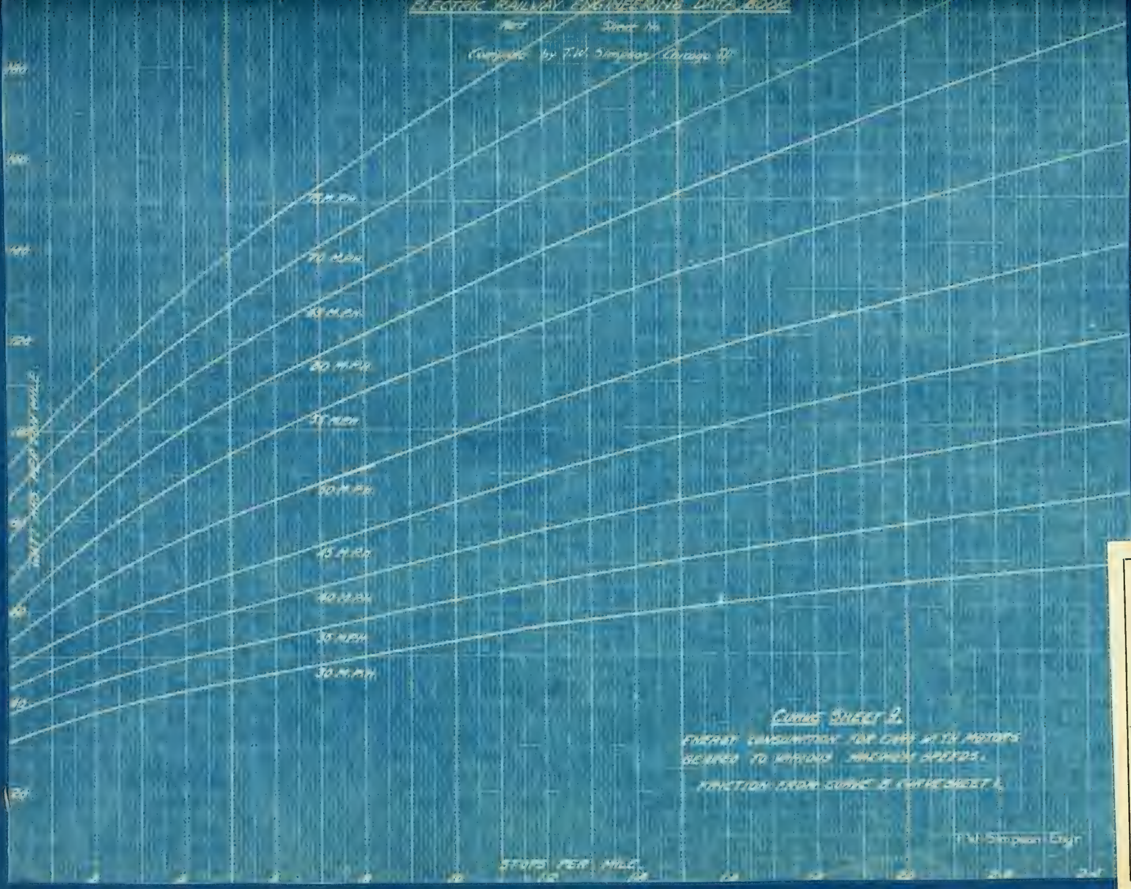
FIGURE No. 87

ELECTRIC RAILWAY ENGINEERING DATA BOOK
Ref. Sheet No.
Compiled by T.W. Simpson Chicago Ill.



Curve Sheet 2.
Energy consumption for cars with motors geared to various maximum speeds.
Friction from curve 2 curve sheet 1.

T.W. Simpson Engr.

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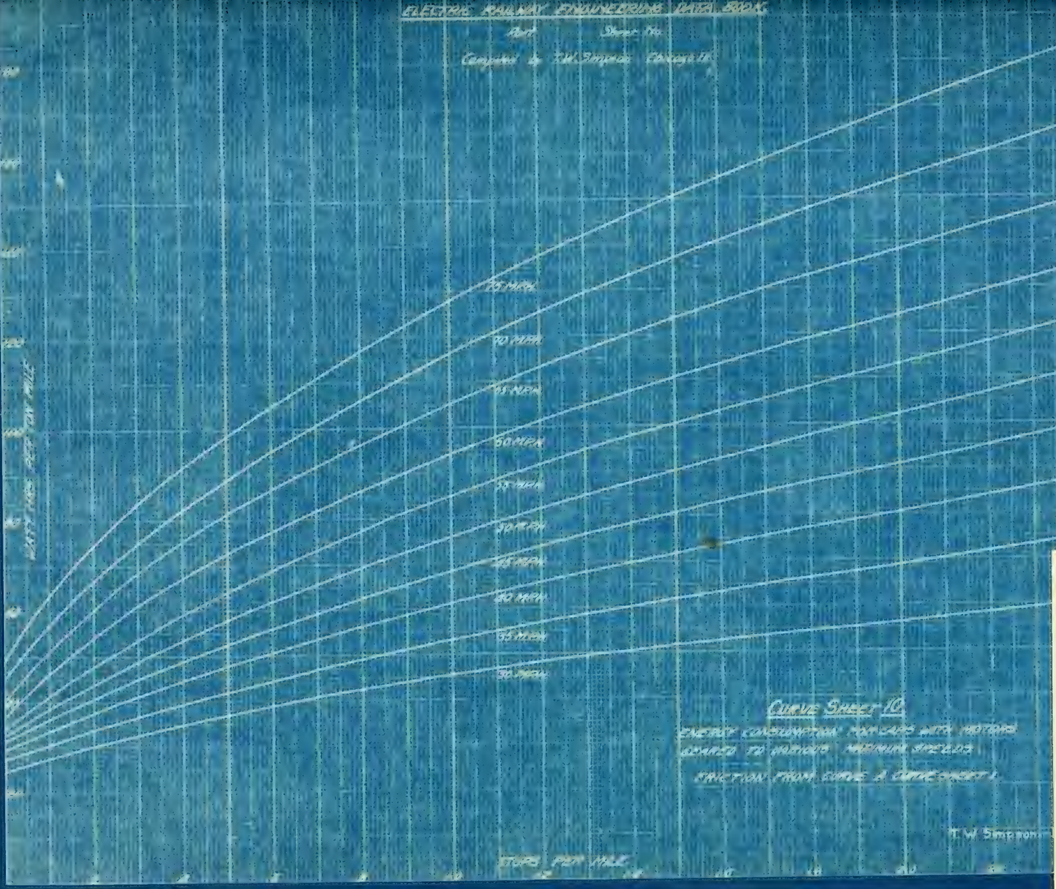
FIGURE No.________



Curve Sheet 10

Energy consumption for cars with motors geared to various maximum speeds.

Friction from curve 2 curve sheet 1.

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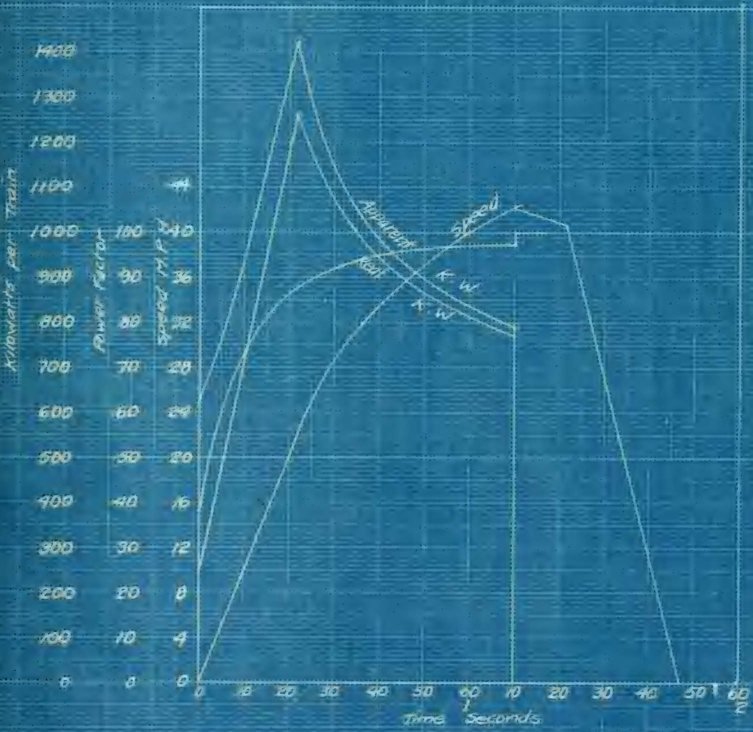
FIGURE No. [illegible]

3 CAR TRAIN
K.W.Hrs. Per run 16.3
Avg. K.W. per train 510



TYPICAL RUN 0.815 MILES
4-Wgh #148 Motors per Car - $37\frac{1}{2}$" Wheels
Gear Ratio $\frac{71}{20}$ = 3.55
9000 / 240 Volts

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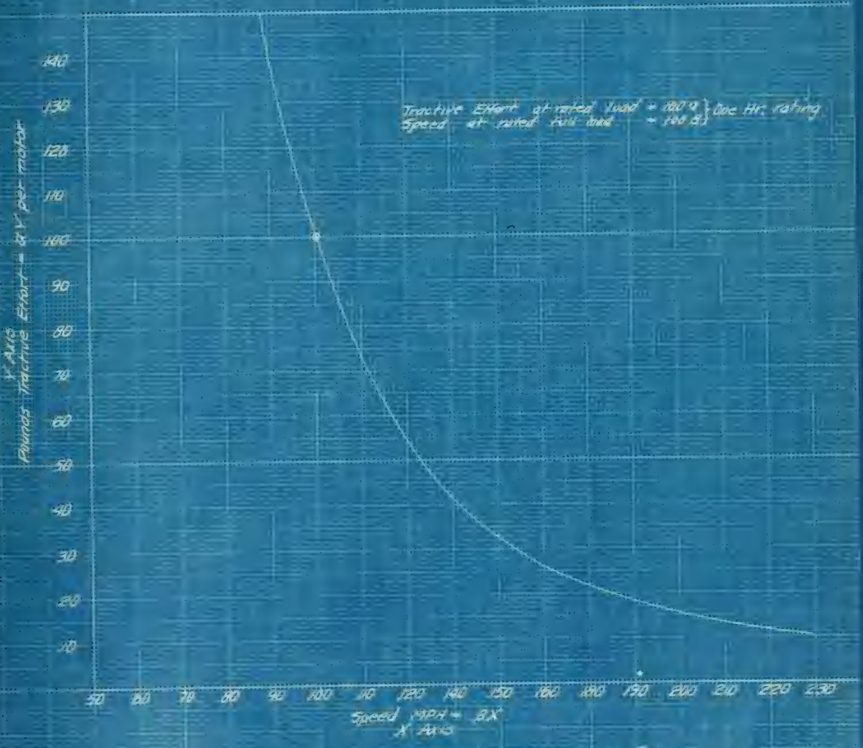
FIGURE No. [illegible]



Tractive Effort at rated load = 100.9 } One Hr. rating
Speed at rated full load = 100.8 }

HP output at point (x=100, y=100) is 26.7 pa

GENERAL SPEED-TRACTIVE EFFORT
for
STANDARD DIRECT CURRENT
SERIES RAILWAY MOTOR

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THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
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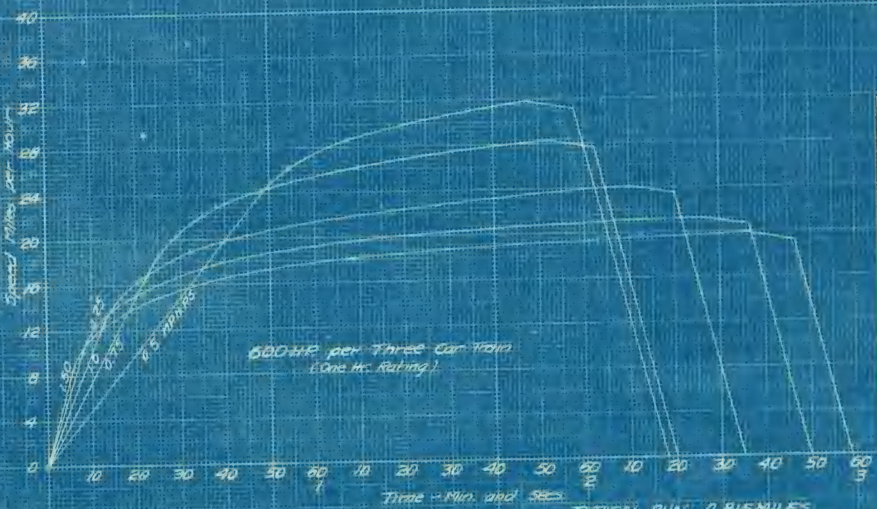
FIGURE No. 21



TYPICAL RUN 0.815 MILES
3 CAR TRAIN 600 HP in D.C. MOTORS PER TRAIN
Geared for various initial accelerations
Current during initial acceleration is
Full load current - One Hr. rating basis
Motor characteristics Fig
Train Friction Fig
Total train weight 170 Tons $HP/_{Ton} = 3.53$

TWS

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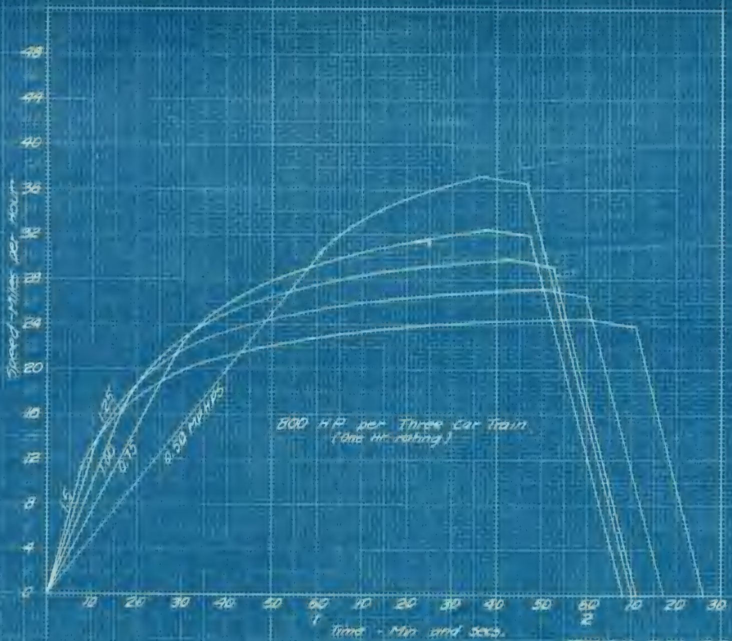
FIGURE No. [illegible]



TYPICAL RUN 0.815 MILES
3 CAR TRAIN 800 H.P. D.C. MOTORS PER TRAIN
Geared for various initial accelerations
Current during initial acceleration is
full load current - One Hr. rating basis
Motor Characteristic Fig.
Train Friction Fig.

Total Train weight 174 Tons $\frac{H.P.}{Ton}$ = 4.60

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SUBURBAN SERVICE AT CHICAGO, ILL.
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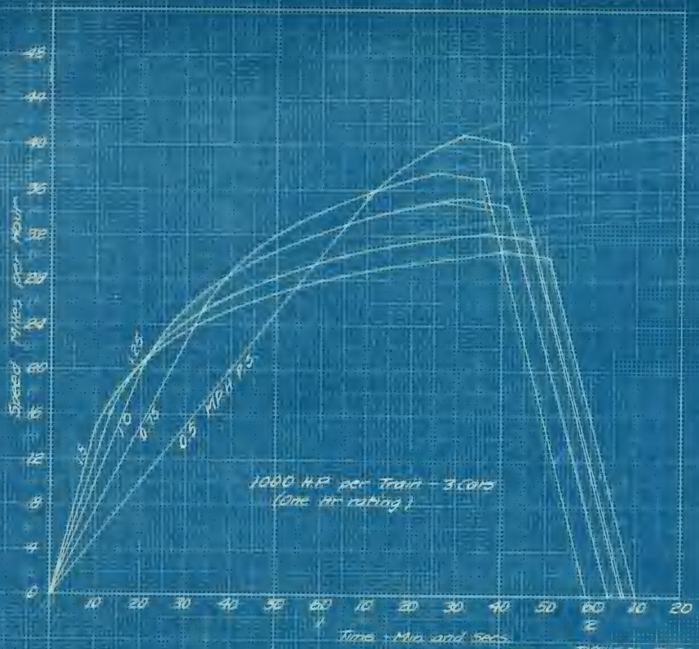
FIGURE No. 93



TYPICAL RUN 0.815 MILES
3 CAR TRAIN - 1000 H.P. D.C. MOTORS PER TRAIN
Geared for various initial accelerations
Current during initial acceleration is
full load current. One hr rating basis
Motor characteristics Fig.
Train Friction

Total Train weight 180 Tons HP/Ton - 5.56

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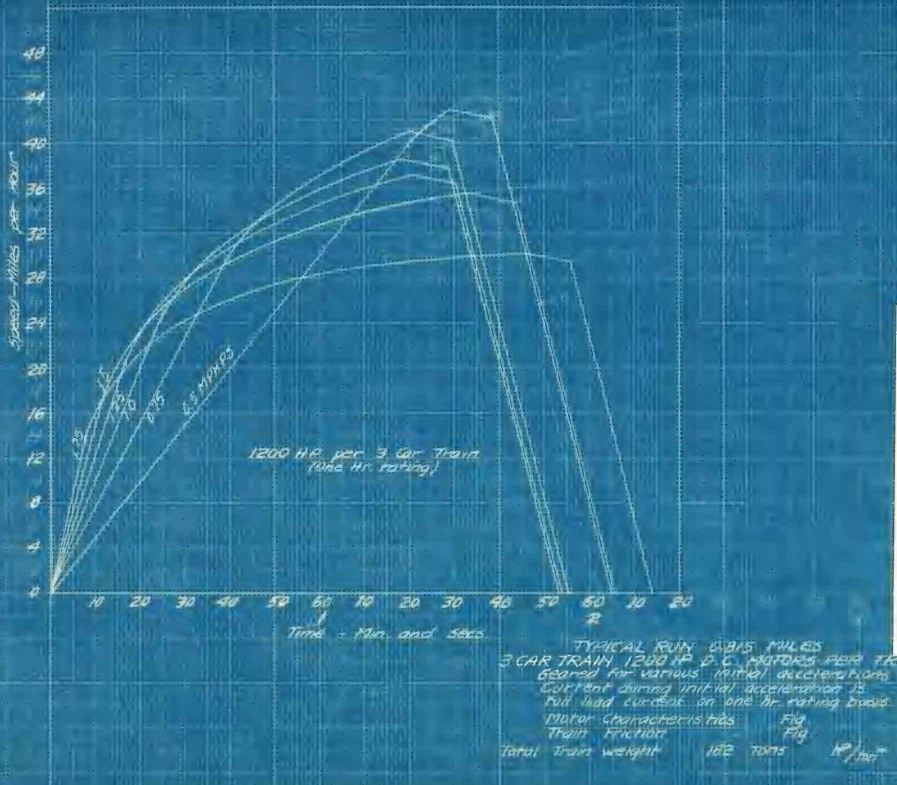
FIGURE No. 94



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SUBURBAN SERVICE AT CHICAGO, ILL.
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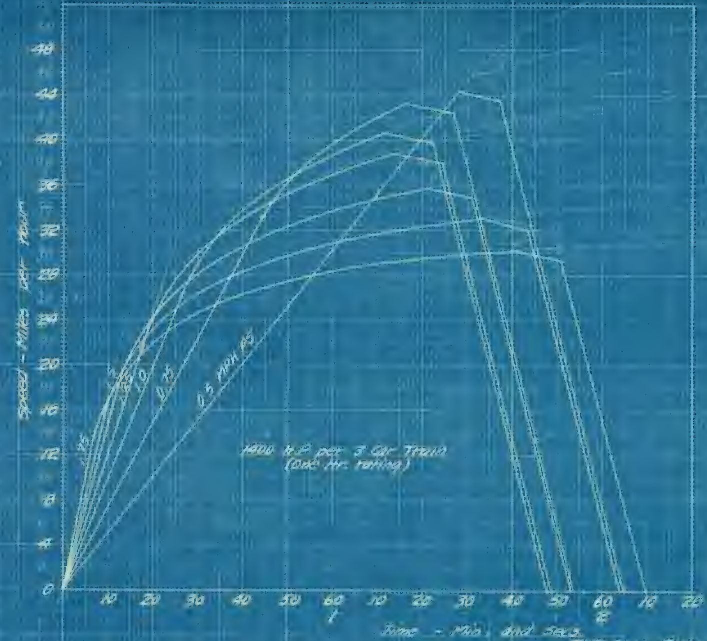
FIGURE No. 95



TYPICAL RUN 0.815 MILES
3 CAR TRAIN - 1400 HP DC MOTORS PER TRAIN
Geared for various initial accelerations
Current during initial acceleration is
Full load current on one hr. rating basis
Motor Characteristic Fig.
Train Friction Fig.
Total Train weight 186 Tons $\frac{HP}{Ton} = 7.52$

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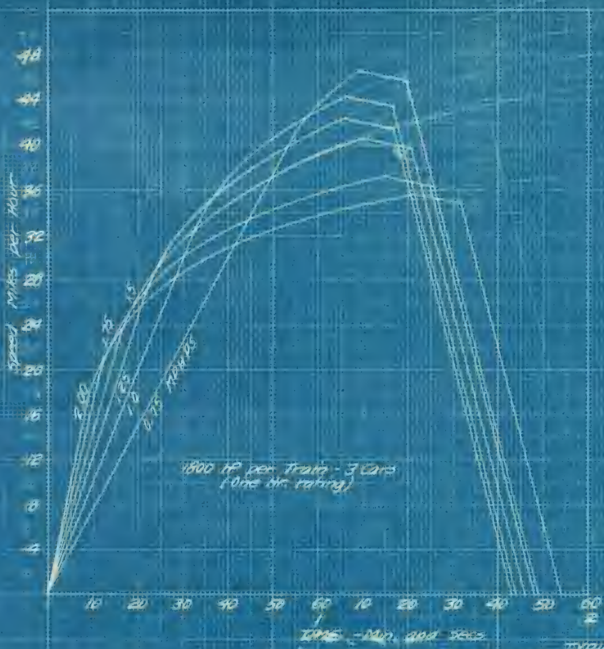
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
TRACY W. SIMPSON

FIGURE No. 36



TYPICAL RUN 0.815 MILES
3 CAR TRAIN 1800 HP DC MOTORS PER TRAIN
Geared for various initial accelerations
Current during initial acceleration is full
load current on one hr basis
Motor characteristics Fig.
Train friction Fig.
Total train weight 192 Tons $\frac{HP}{Ton}$ = 9.35

ELECTRIFICATION PROJECT
THE ILLINOIS CENTRAL RAILROAD CO.
SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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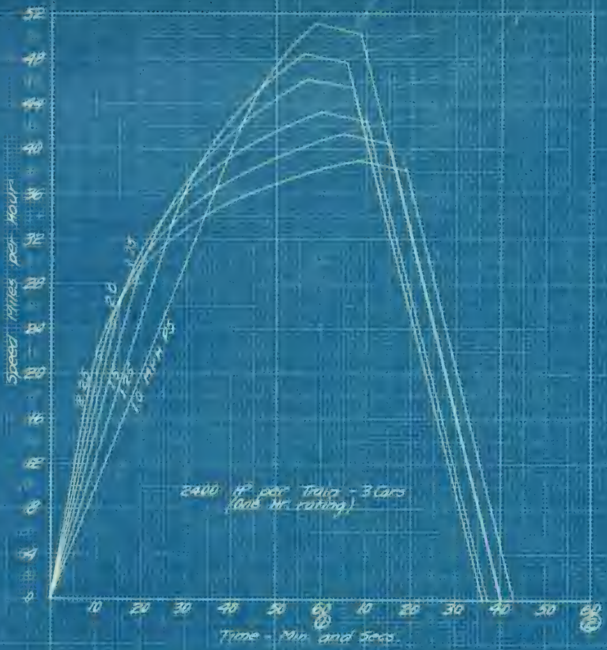
FIGURE No. 37



TYPICAL RUN 0.815 MILES
3 CAR TRAIN 2400 H.P. D.C. MOTORS
Geared for various initial accelerations
Current during initial acceleration is full
load current on one hour rating basis
Motor characteristics Fig.
Train resistance Fig.
Total train weight 204 Tons H.P./Ton = 11.8

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SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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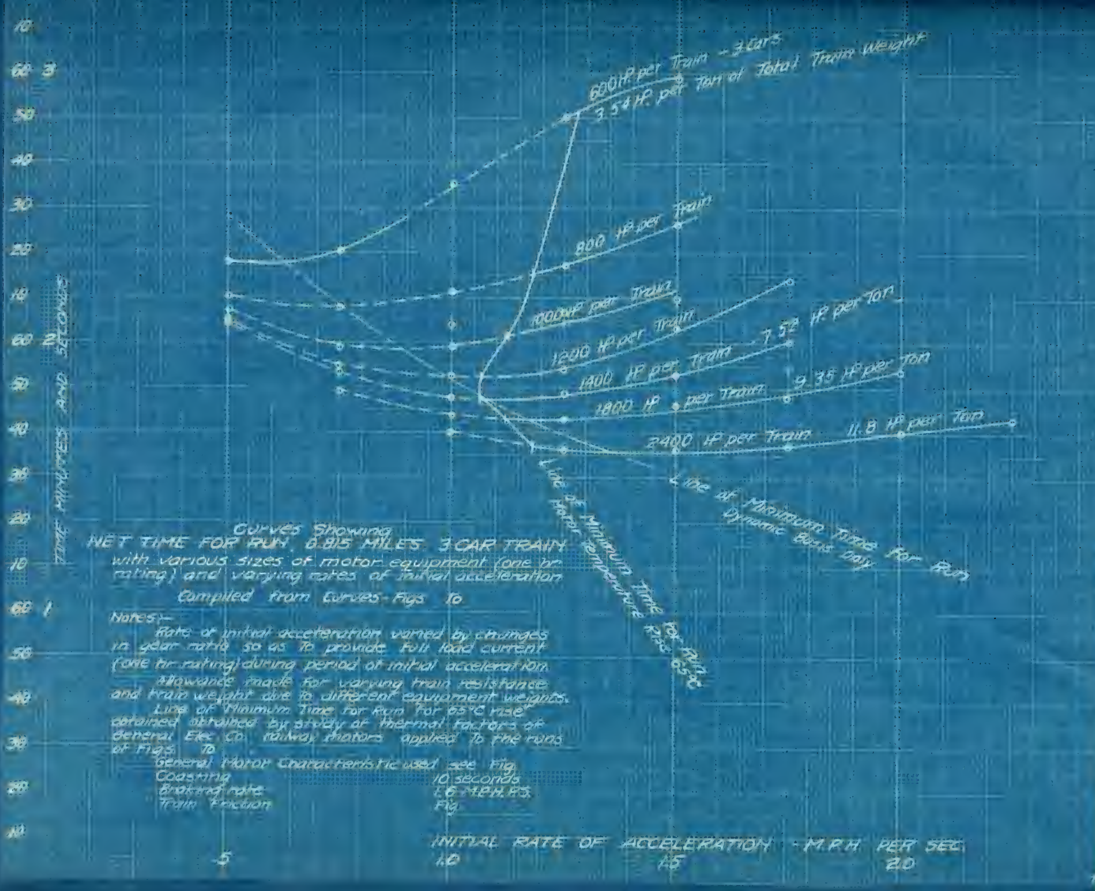
FIGURE No. 32



Curves Showing
NET TIME FOR RUN, 0.815 MILES, 3 CAR TRAIN
with various sizes of motor equipment (one hr. rating) and varying rates of initial acceleration

Compiled from Curves - Figs. 10

Notes:-

Rate of initial acceleration varied by changes in gear ratio so as to provide full load current (one hr. rating) during period of initial acceleration.

Allowance made for varying train resistance and train weight due to different equipment weights.

Line of "Minimum Time for Run for 65°C rise" obtained obtained by study of thermal factors of General Elec. Co. railway motors applied to the runs of Figs. 10

General Motor Characteristic used see Fig.

Coasting	10 seconds
Braking rate	1.6 M.P.H.P.S.
Train Friction	Fig.

ELECTRIFICATION PROJECT
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SUBURBAN SERVICE AT CHICAGO, ILL.
BY
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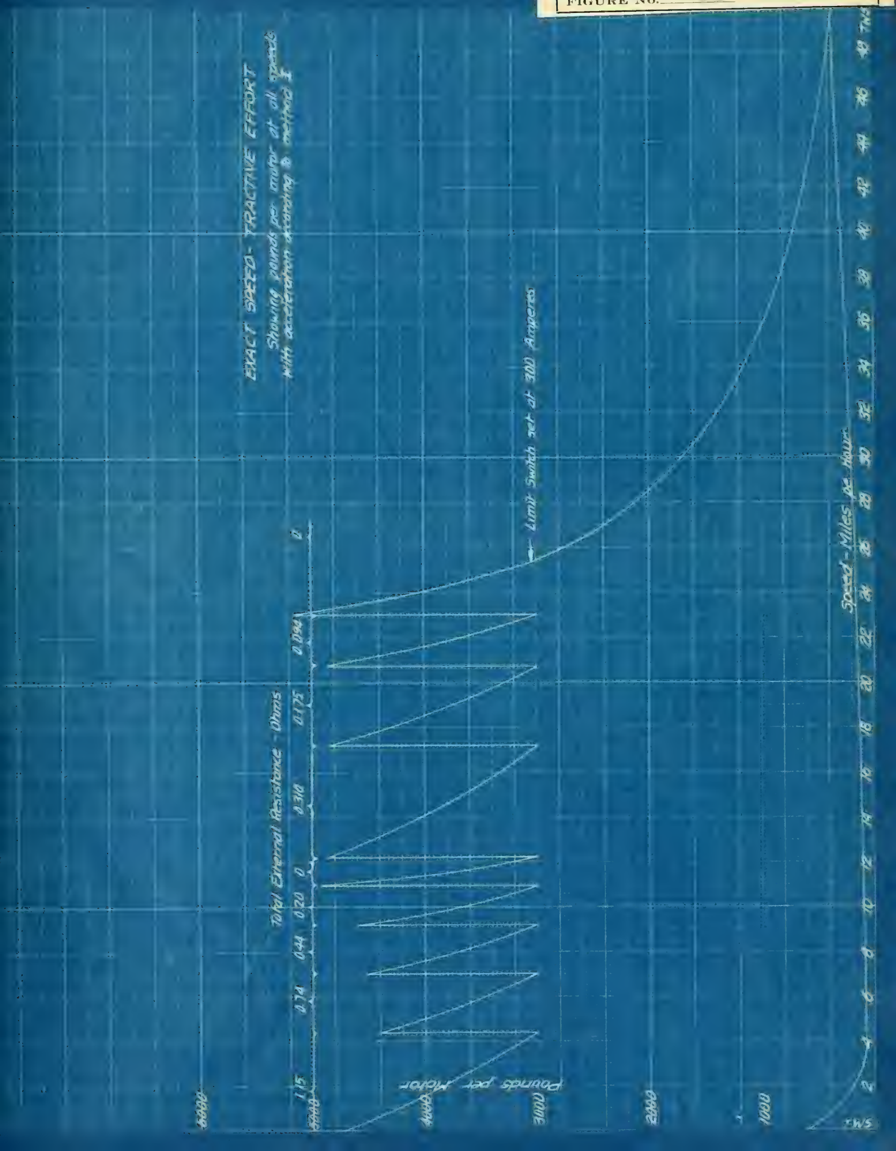
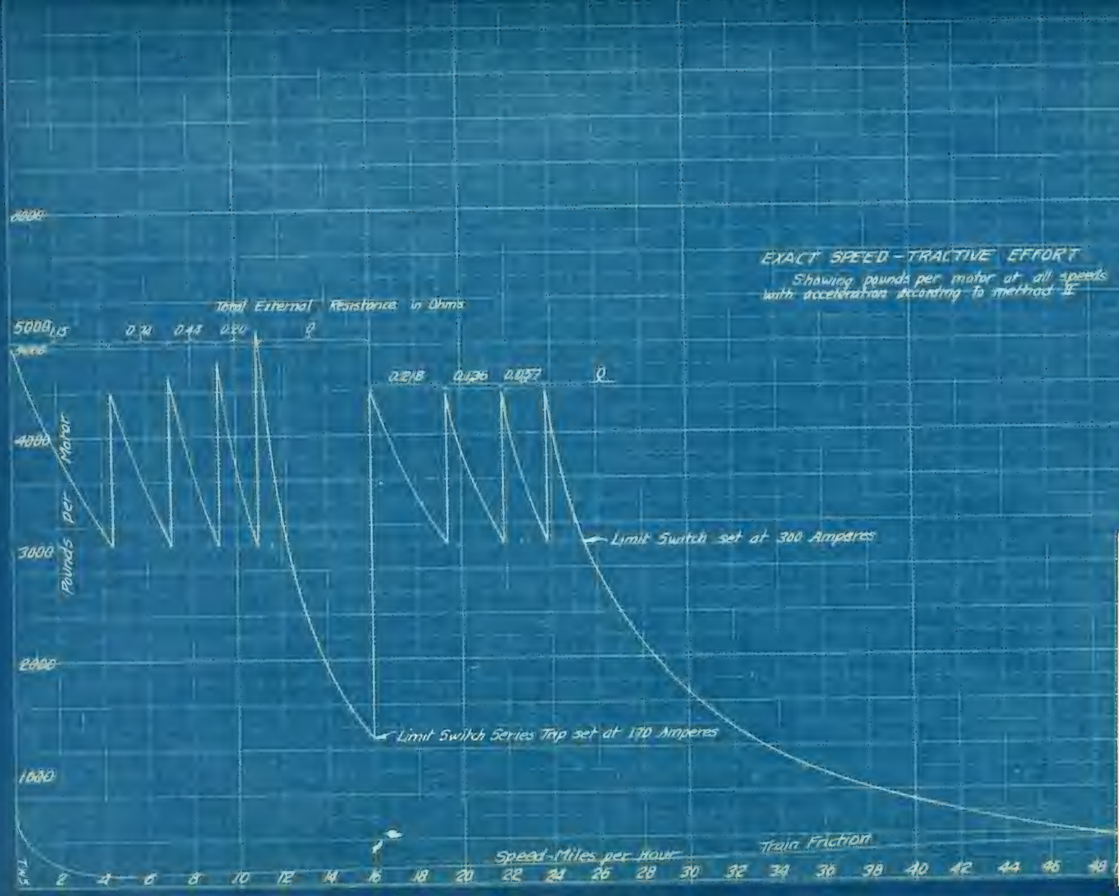
FIGURE No. 33




EXACT SPEED - TRACTIVE EFFORT

Showing pounds per motor at all speeds with acceleration according to method II

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FIGURE No. 180

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FIGURE No. 101

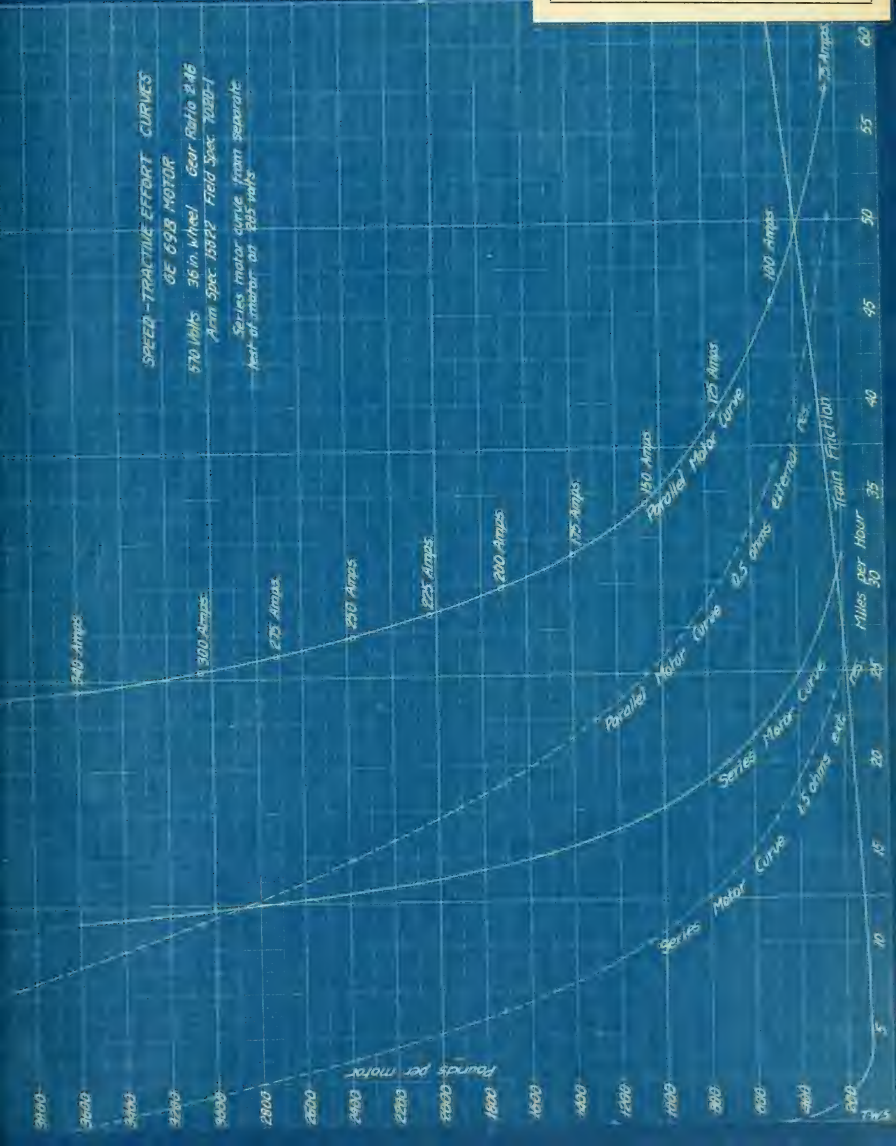

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FIGURE No. 152

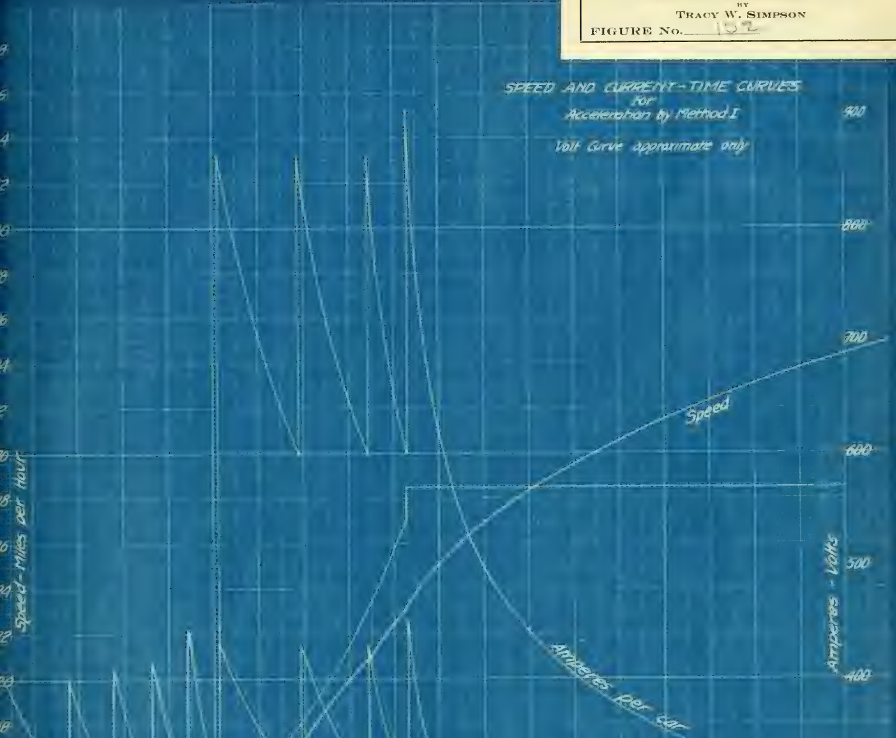

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FIGURE No. 103

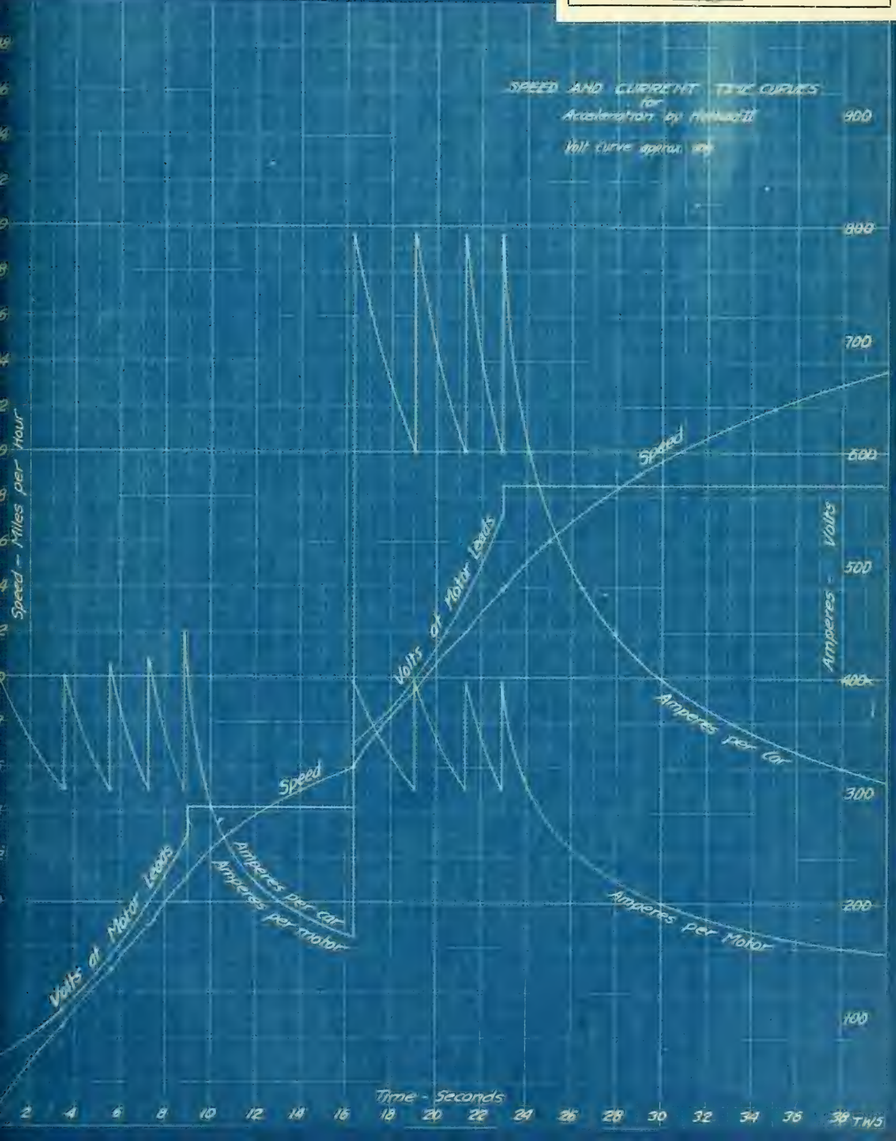

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FIGURE No. [illegible]

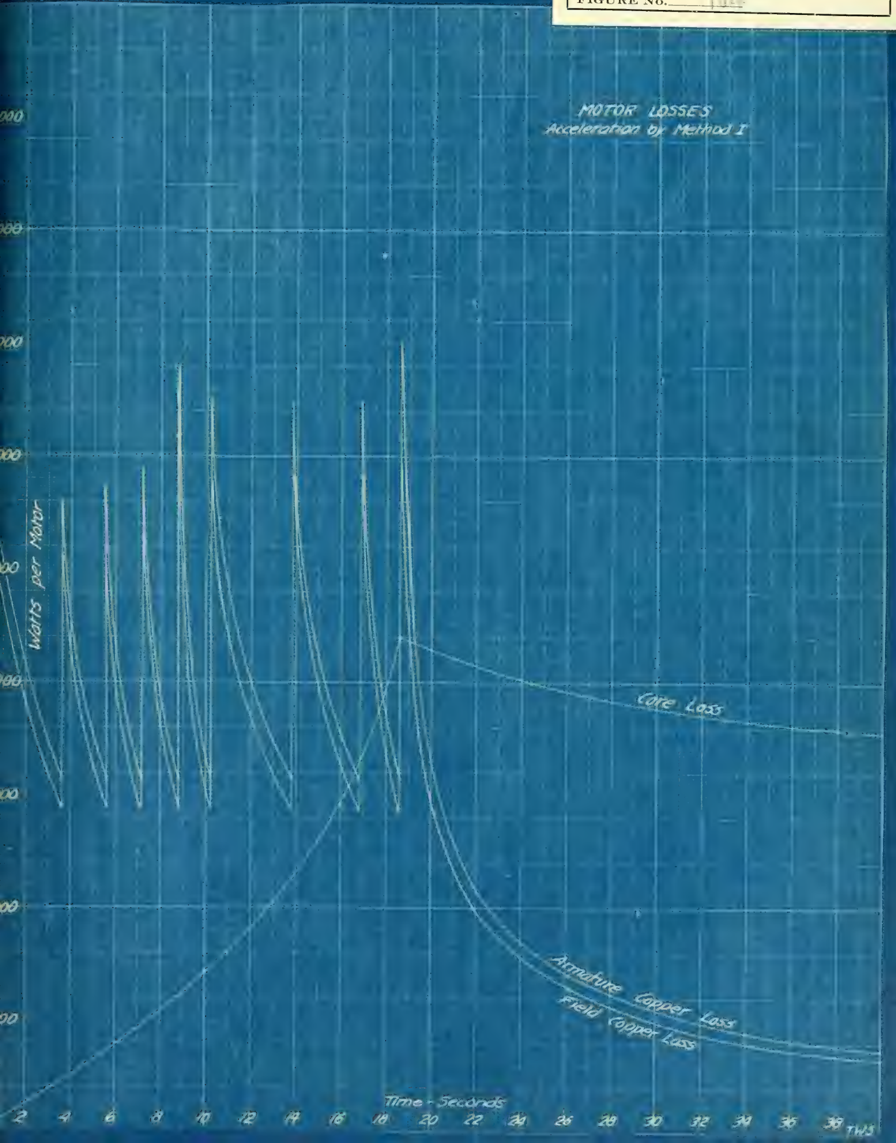

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FIGURE No. 15

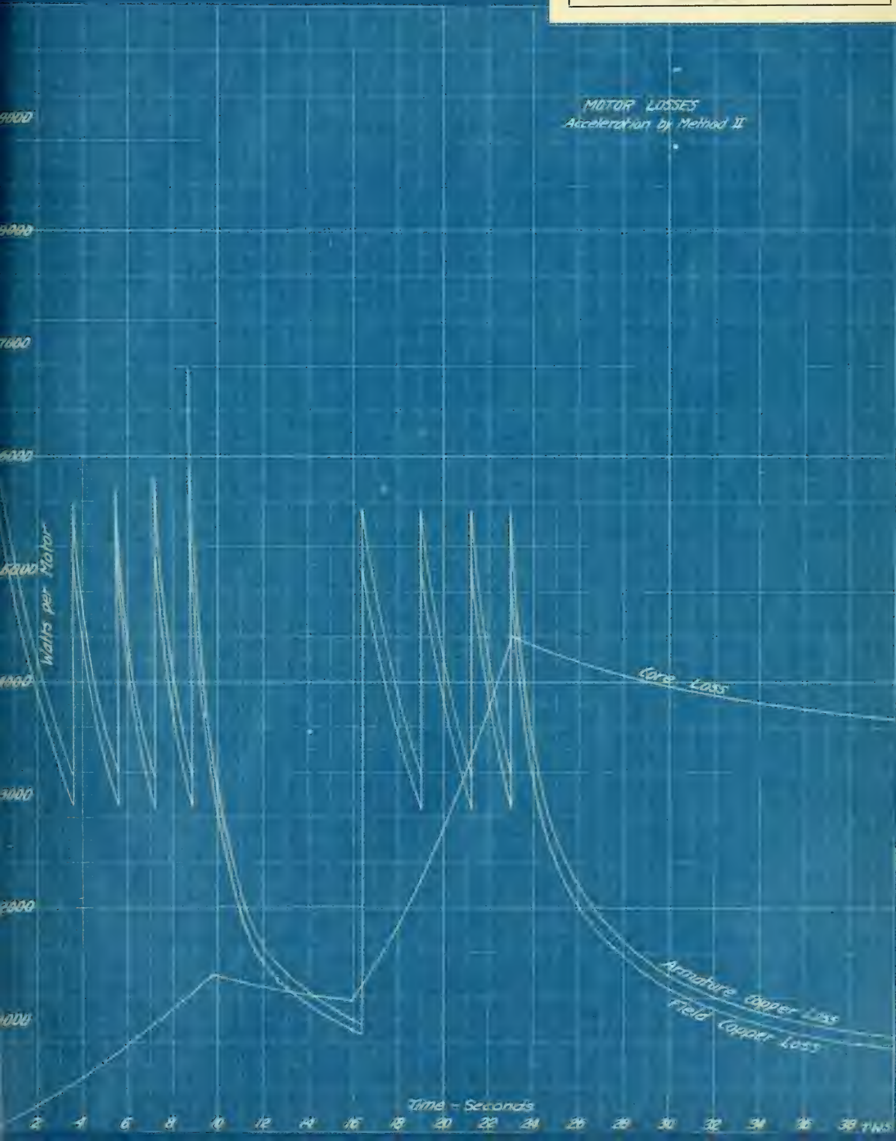

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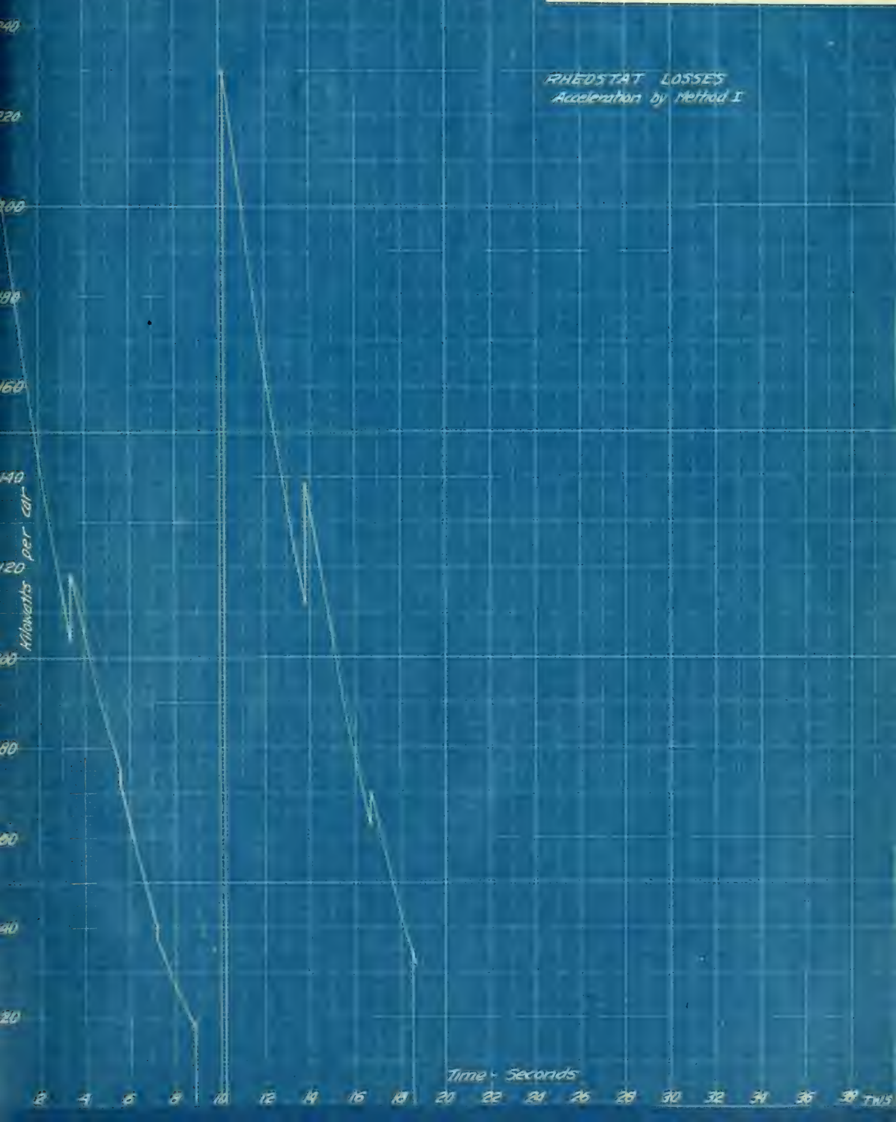
FIGURE No. 106



ELECTRIFICATION PROJECT
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FIGURE No. [illegible]

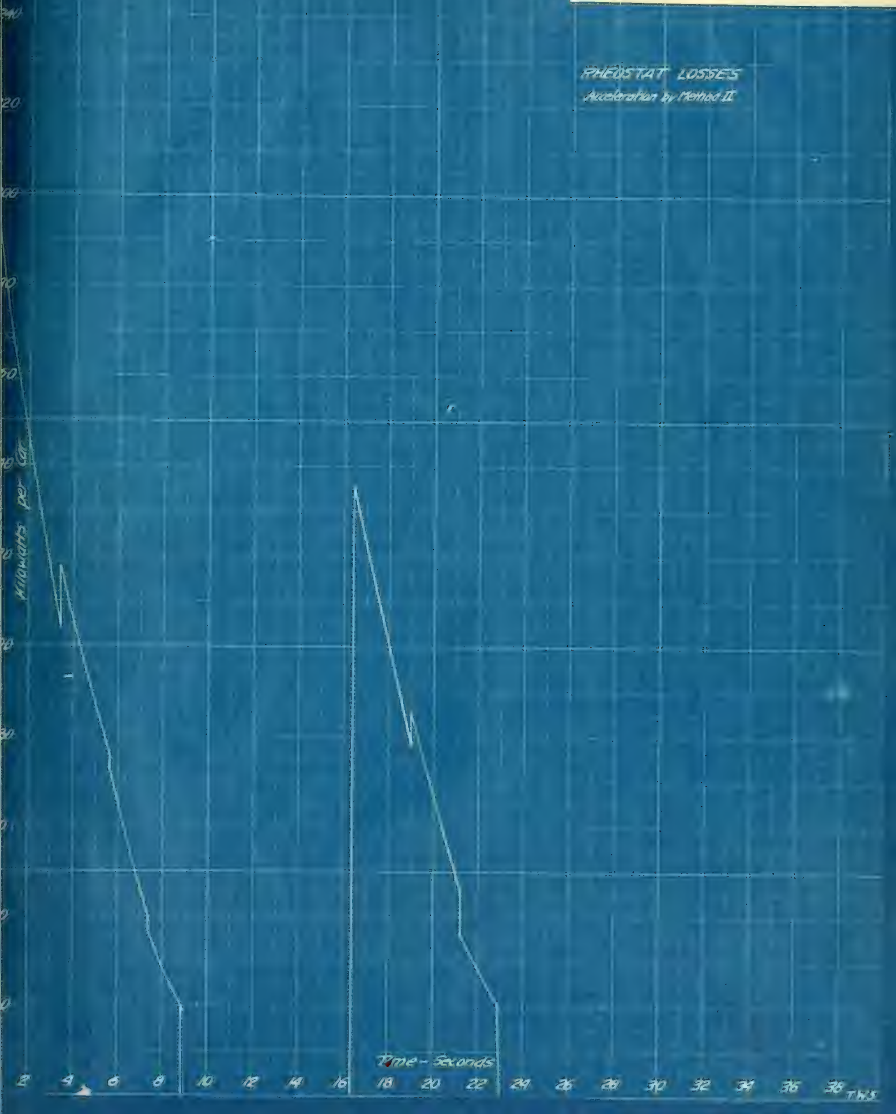

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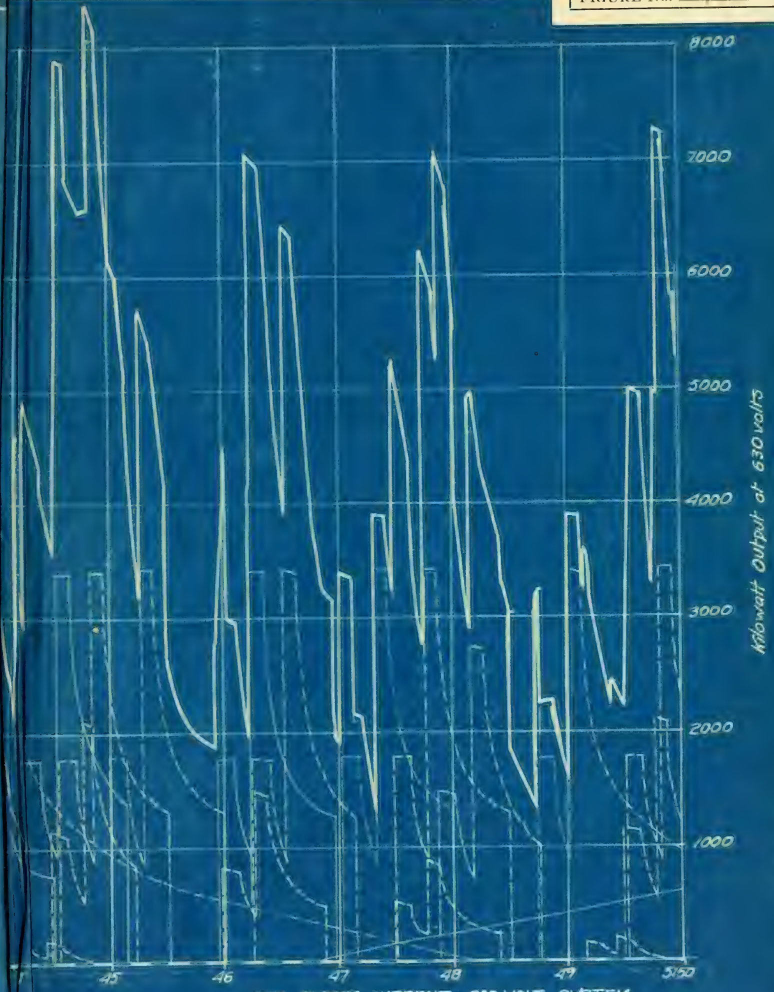
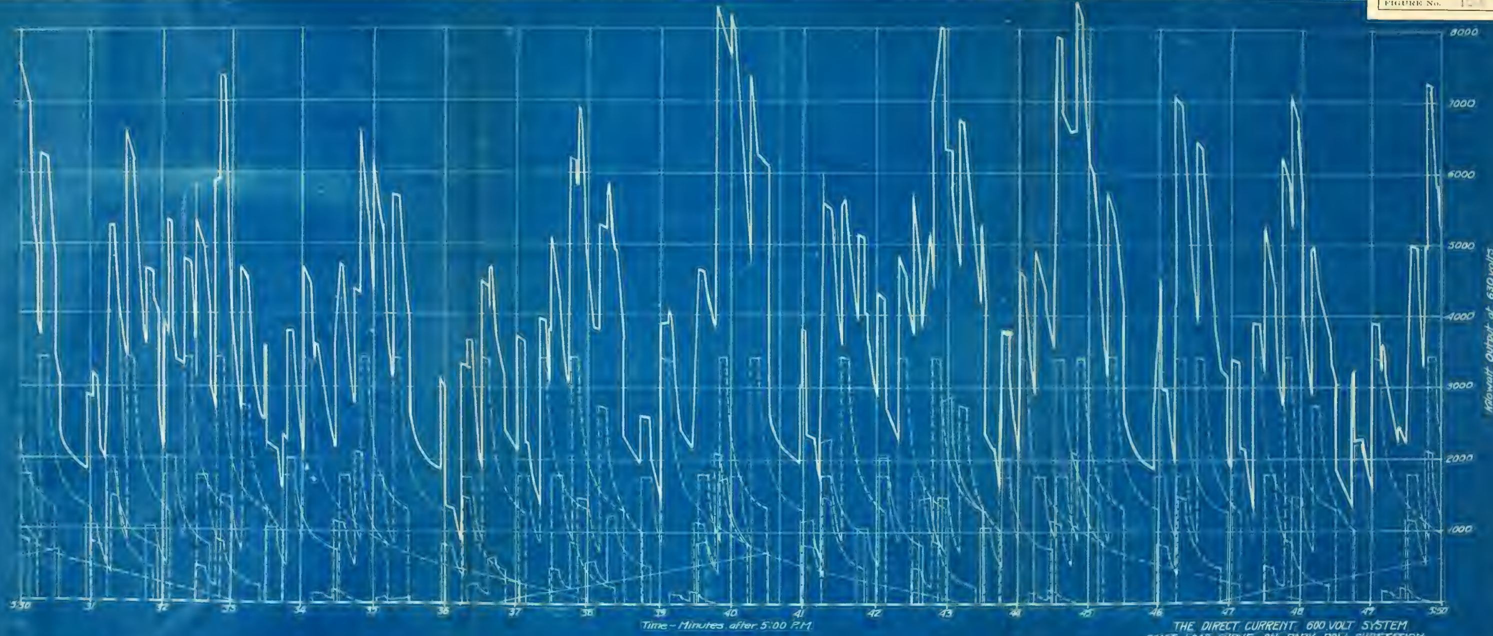
FIGURE No. 108



THE DIRECT CURRENT 600 VOLT SYSTEM
EXACT LOAD CURVE ON PARK ROW SUBSTATION.
taken for period from 5:30 P.M. to 5:50 P.M.
FOR SUMMER SEASON
Trains operating according to Provisional Schedule of Fig. 44.

THE ILLINOIS CENTRAL RAIL
SUBURBAN SERVICE AT CHICAG
BY
TRACY W. SIMPSON
FIGURE No. [illegible]



THE DIRECT CURRENT 600 VOLT SYSTEM
EXACT LOAD CURVE ON PARK ROW SUBSTATION.
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Trains operating according to Provisional Schedule of Fig. 44.